SWEEP

SOIL AND WATER

ENVIRONMENTAL

ENHANCEMENT PROGRAM

PAMPA

PROGRAMME D'AMELIORATION

DU MILIEU PEDOLOGIQUE

ET AQUATIQUE

Canada

Ontario

SWEEP

is a $30 million federal-provincial agreement, announced May 8, 1986, designed to improve soil and water quality in southwestern Ontario over the next five years.

PURPOSES

There are two interrelated purposes to the program; first, to reduce phosphorus loadings in the Lake Erie basin from cropland run-off; and second, to improve the productivity of southwestern Ontario agriculture by reducing or arresting soil erosion that contributes to water pollution.

BACKGROUND

The Canada-U.S. Great Lakes Water Quality Agreement called for phosphorus reductions in the Lake Erie basin of 2000 tonnes per year. SWEEP is part of the Canadian agreement, calling for reductions of 300 tonnes per year — 200 from croplands and 100 from industrial and municipal sources.

PAMPA

est une entente fédérale-provinciale de 30 millions de dollars, annoncée le 8 mai 1986, et destinée à améliorer la qualité du sol et de l'eau dans le Sud-ouest de l'Ontario.

SES BUTS

Les deux buts de PAMPA sont: en premier lieu de réduire de 200 tonnes par an d'ici 1990 le déversement dans le lac Erie de phosphore provenant des terres agricoles, et de maintenir ou d'accroître la productivité agricole du Sud-ouest de l'Ontario, en réduisant ou en empêchant l'érosion et la dégradation du sol.

SES GRANDES LIGNES

L'entente entre le Canada et les États-Unis sur la qualité de l'eau des Grands Lacs prévoyait de réduire de 2 000 tonnes par an la pollution due au phosphore dans le bassin du lac Erie. PAMPA fait partie de cette entente qui réduira cette pollution de 300 tonnes par an — 200 tonnes provenant des terres agricoles et 100 tonnes provenant de sources industrielles et municipales.

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VOLUME VII

MACRO-ECONOMIC IMPACT ASSESSMENT OF SOIL CONSERVING TECHNOLOGIES (SWEEP)

Prepared for:

Agriculture Canada
for the
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TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

TABLE OF CONTENTS (cont.)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (cont.)

EXECUTIVE SUMMARY

Farm level activities which impact on the rate and level of soil loss have significant consequences for various "down-stream" stakeholders, such as:

- municipalities concerned with drinking water quality;
- harbour authorities concerned with soil sediment build-ups; and
- recreationists concerned with wildlife habitats and swimming activities.

This report examines the various linkages between farm level soil loss and the economic impact on these and other "downstream" consequences.

One of the major goals of this report is to estimate the economic impact of off-farm downstream impacts resulting from a reduction in sediment and phosphorus run-off. Based on the current analysis, this report indicates that a 10 percent reduction in soil erosion lowers annual downstream costs by $3 per hectare and a 40 percent reduction lowers annual downstream costs by $12 per hectare.

1.0 INTRODUCTION

This report contains an assessment of the macro-economic impact associated with reduced soil loss from Ontario farms. The results of this document are summarized in Section 5.0 of Volume I of this series.

1.1 OBJECTIVES

The objective of this study is to evaluate the broader "downstream" social impacts associated with various farm levels of soil loss reduction. Specifically, for a given level of soil or phosphate loss reduction, we calculate the likely cost savings to various stakeholder groups concerned about the following:

- water conveyance -- ditch dredging near farm fields;
- sport fishing -- stream, river and lake;
- natural aesthetics and wildlife;
- water flow control -- rivers and lakes;
- water transportation;
- commercial fishing;
- recreational boating; and
- swimming.

1.2 SCOPE

This report relates to the range of possible "downstream" impacts associated with soil/phosphate loss from farm fields. The linkages and estimated cost impact are generic in nature and are not intended to represent a specific watershed. However, we utilize collected data and information from the three PDW watersheds as a starting point for our analysis.

Data and information is derived from a variety of sources, but relies heavily on expert consensus opinion.

1.3 ORGANIZATION OF THIS REPORT

This report is Volume VII of a seven volume series, consisting of:

Volume I:	An Economic Evaluation of Soil Tillage Technologies: Summary Report
Volume II:	Collection and Analysis of Field Data From PDW
Volume III:	Field Level Economic Analysis of Changing Tillage Practices in Southwestern Ontario
Volume IV:	An Economic Evaluation of the Tillage 2000 Program in Ontario
Volume V:	An Economic Assessment of the Technology Evaluation and Development (TED) Program
Volume VI:	Watershed Level Economic Analysis of Tillage Practices in Southwestern Ontario
Volume VII:	Macro-Economic Impact Assessment of Soil Conserving Technologies

This document consists of ten sections. The next section, (2.0), reviews the approach that is used to estimate the macro-economic impact of soil conservation. Subsequent sections pertain to downstream impacts from various perspectives.

In Section 3.0, the biological and physical processes that affect the degree of off-farm impact due to soil erosion are discussed. The three pilot demonstration watersheds that provide the analytical starting point for this assessment are overviewed in Section 4.0.

The methodology used to estimate off-farm impacts and the assumptions regarding physical sedimentation and phosphorus properties are the focus of Section 5.0. This approach is used to discuss the impacts on priced market activities, provision of government services, recreational activities, and natural processes. These are reported in Sections 6.0, 7.0, 8.0 and 9.0 respectively. A summary of the off-farm and downstream impact is presented in Section 10.0.

2.0 AN OVERVIEW ON THE IMPACT OF CONSERVATION

In this section, our general approach to addressing the impact of soil conservation is outlined.

2.1 CONCEPTUAL APPROACH

The overall approach to assessing off-farm consequences of soil and water conservation should involve three specific types of impact. These include:

1. The impact on the input supply sector that results from conservation practices having an affect on inputs used in farming;
2. The impact on the commodity output sectors that results from conservation practices affecting the level and composition of output, including the share of various cash crops and livestock outputs; and
3. The impact on downstream activities that occur due to conservation practices having an affect on the provision of government services (such as water treatment, water flood control), fishing and recreational/aesthetic activities.

The stakeholders of improved cropland conservation include:

1. farmers and agricultural land owners;
2. agri-business including input suppliers and distribution/processors of agricultural production;
3. business interests providing goods and services downstream from the land resources;
4. the general public consuming goods and services downstream from the agricultural sector;
5. government; and
6. taxpayers.

The above impact areas of conservation do not involve all six sets of stakeholders. As shown in the following figure, some stakeholders are only affected by one or two impact areas (Figure 2.1). The approach and methodology, and impact outlined in the remainder of this report pertain to off-farm downstream impacts alone. Thus, the stakeholders impacted by downstream activities do not directly include farmers and agribusiness. It should be noted that impacts can not always be added across stakeholders. In some situations, a double counting of impact may occur by adding across.

The targeting of conservation activities occurs at the micro level, which is either the field or the farm. To arrive at more aggregate consequences of conservation technologies, the conceptual approach starts at the farm level (for the on-farm economic analysis), at the pilot watershed level (for the downstream impacts), and at the larger watersheds for extrapolation of impact.

At the same time, our approach must be guided by an important SWEEP objective, which is to reduce phosphate loadings from Ontario crop land by 200 tonnes per year. The approach, therefore, has to account for the economic impact of reducing phosphate run-off, even if the impact occurs downstream from the pilot watershed.

2.2 IMPACT OF CONSERVATION AT THE FARM LEVEL

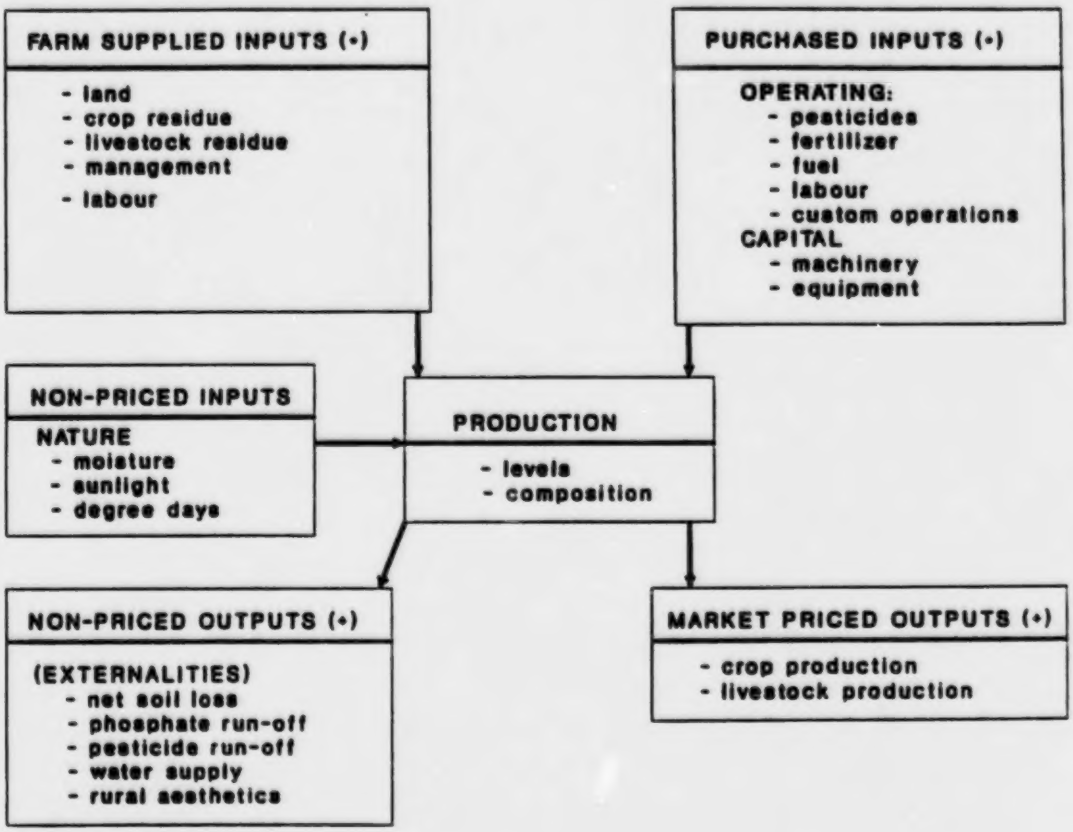
The farm as a production unit uses various inputs to produce marketable outputs. With current and prospective farm production technologies, the farm production unit also produces non-priced outputs, or externalities. This production relationship is illustrated in Figure 2.2.

Figure 2.1 Impact by Stakeholder

Stakeholder	IMPACT AREAS		
	Farm Inputs	Farm Outputs	Downstream Activities
Farmers	X	X	
Agri-Business	X	X	
Downstream Businesses			X
Downstream Consumers & Public			X
Government			X
Taxpayers			X

Figure 2.2 Impact of Conservation Activities on Farm Level Inputs and Outputs

* inputs that can be affected by conservation activities
\+ outputs that can be affected by conservation activities



On the inputs side, the farm unit purchases operating and capital inputs. As well, the farm itself supplies inputs such as land and management, and non-marketed by-products such as crop and livestock residues.

Non-priced, non-farm specific inputs are provided by nature to the farm operation. These are moisture and sunlight, which in various combinations are essential for biological production processes.

Farm production results in two types of outputs - those that are priced in an organized market and those that are not. The priced outputs are the products sold off the farm, including corn, soybean, other cash crops and livestock.

The non-priced outputs, or externalities, include:

1. those products used or produced in the production process that leave the farm suspended in water flow (i.e., sediment and phosphorus);
2. water itself; and
3. the aesthetics of farm and rural settings.

On a theoretical plane, conservation technologies can affect the compositional value of inputs and farm supplied inputs, and either of these can alter production levels (see Figure 2.2). In turn, changes in production levels can impact on market priced outputs. Externalities can be affected by the conservation practice itself, through the altered level and composition of output, or by a combination of these phenomena.

It is anticipated that conservation practices will decrease with the volume of materials suspended in the water that leaves the farm. That is, some of the externalities produced by the farm, should be less negative (more beneficial).

2.3 IMPACT OF CONSERVATION ON OFF-FARM ACTIVITIES

The potential areas of impact at the watershed level (both pilot watersheds and larger watershed areas) are highlighted in Figure 2.3.

As indicated, an impact can occur in the following sectors:

1. Farm input supply sector;
2. Farm sector;
3. Post farm gate activity (value added) sector; and
4. Downstream activities.

As noted previously, this report focuses on analysis of downstream impact only. Most recreational downstream impact will likely be measured in terms of both a benchmark (control) and the impact. These measurements stem from the organization of most downstream activities on a watershed basis.

For priced downstream market activities, such as water transportation and commercial fishing, assessing impact requires the existence of a relationship between reduced sediment and phosphate run-off and the resulting impacts.

Relationships for commercial fishing will consider the impact of phosphate and sediment levels on commercial fish populations (and their food sources) and resulting commercial fish catches. In the case of providing government services such as water treatment, many of the services are provided, or can be identified on a watershed basis. Thus the benchmark for these services will likely be an average annual cost of providing such services. The impact is the calculated financial savings or expenditures required to provide such services.

To measure the impact on recreational activities, documentation underlying physical and cultural relationships in each of the watersheds is first required. For example, the level of phosphate (eutrophy) and the frequency of closing public beaches will be compared.

Figure 2.3 Impact of Conservation Activities at the Watershed Level

FARM INPUT SUPPLY SECTOR

- equipment
- fertilizer
- pesticides
- seed
- credit

FARM SECTOR

- crop protection
- livestock production
- expenses
- net income
- net soil loss
- phosphate run-off
- pesticide run-off
- water supply
- rural aesthetics

DOWNSTREAM ACTIVITIES

Priced Market Activities

- water transportation
- commercial fishing

Government Services

- water conveyance
- water flow control
- drinking water treatment
- small craft harbour dredging
- large vessel harbour dredging
- watershed authorities

Non-Priced Activities

- swimming
- boating
- sport fishing
- wildlife natural aesthetics

Natural Processes

- habitat regeneration

POST FARM GATE ACTIVITIES

- crop storage
- crop processing
- livestock processing
- transportation

The set of activities that will be undertaken to quantify potential impact areas includes, documenting the physical relationships and developing the approach to measure the impact of improved upstream conservation. Once the basic physical relationships and direct impact measures have been finalized, then indirect impact measures can be assessed based on a number of assumptions.

The following sections outline how to proceed with measuring the impact of conservation on downstream activities. Our approach is based on a synthesis of published research and expert opinion, and on developing a logical analytical framework to trace impacts from the time potential agricultural contaminants enter a waterway until they are eventually transported to the lake environment.

Consequently, the next section explains those biological and physical processes necessary to understanding how sediment, phosphorus and pesticides affect downstream activities.

3.0 BIOLOGICAL AND PHYSICAL PROCESSES

This section of the report focuses on the off-site economic benefits and costs of soil erosion conservation efforts. Assessment of the benefits is based on the existence of relationships between reduced sediment, phosphate and potential pesticide run-off, and the resulting impact on downstream activities. Assessment of these benefits/costs are important in determining the economic value of soil and water conservation practices.

3.1 INTRODUCTION

The objectives of SWEEP (TED Bulletin, 1989) are:

1) To reduce phosphorus loadings of the Lake Erie basin from cropland run-off; and

2) To improve the productivity of southwestern Ontario agriculture by reducing the soil erosion that contributes to water pollution.

The benefits of soil conservation and a reduction in phosphorus loadings can be in the form of inputs to production (e.g., fish production) or to consumer goods (e.g., recreation/ aesthetic activities). It has been documented (U.S. Army Corps, 1982) that as the overall level of soil erosion decreases, the level of pollutants (e.g., sediment and phosphorus) in a waterway also decreases. This in turn potentially increases economic, recreational and aesthetic benefits as the harmful effects of pollutants decrease with diminishing pollutant levels. It is therefore anticipated that the use of conservation practices will be negatively correlated with the volume of materials suspended in the water leaving the farm.

One of the aspects of SWEEP is to study and generate information about the off-farm effects of erosion from cropland, and to evaluate the cost of

conservation technology, or a set of technologies, against the benefits of applied conservation. This information will assist in designing conservation policies and in implementing strategies. This study, therefore, examines the benefits of reduced sediment, phosphorus and pesticide yields to a number of off-farm activities as shown in Figure 2.3.

3.2 PHYSICAL AND BIOLOGICAL PROCESS

Understanding the basic physical and biological processes of soil erosion and sedimentation is essential to the economic valuation of the above activities. Unfortunately, the complexity of physical, chemical and biological linkages create some important limitations to economic analysis. The reasons are:

1) There is limited information on relationships between the implementation of soil conservation practices and changes in downstream sediment, phosphorus and pesticide levels; and

2) It has been impossible for researchers to identify ways in which people react to changes in sediment, phosphorus and pesticide levels alone - as all biological and physical parameters (e.g., water quality, contaminant levels etc.), are linked. It is therefore difficult to separate each biological process to show the result on individual activities.

The extent of off-site damages from soil erosion are not well known, especially at a regional level (Ribaudo, 1988). Many assumptions are therefore required in this study to estimate the impacts of off-site damages on both a regional watershed level and overall provincial basis. Relationships between levels of sediment, phosphorus and pesticide run-off, and the resultant effect on downstream activities are not easily defined. Through the assistance of published reports, collection of primary data and through personal correspondence with experts in various subject areas, assumptions about these relationships are made to complete the analysis.

The first task, therefore, is to outline sources of pollution and reveal how agriculture contributes to water pollution. The degree to which agriculture is a contributor to the pollution to our waterways is very important, both economically and environmentally.

3.3 SOURCES OF POLLUTION

Soil erosion is a major cause of non-point source pollution, that is "pollution that is not discharged from a sewer, industrial discharge pipe, or other point source," (Clark, 1987). Non-point agricultural sources include cropland, rangelands and pasture land and are thought to be the major contributors both of conventional pollutants, such as sediment, and dissolved solids and of chemical pollutants. Other non-point sources not included in farmland erosion are storm water run-off from urban streets and industrial plants, mine drainage and a very small proportion from septic tank leakage. Various analyses indicate that cumulative non-point sources contribute as much as 73 percent of total biochemical oxygen demand (BOD) loadings, 99 percent of suspended solids, 83 percent nitrogen, 84 percent phosphorus and 98 percent bacterial loads in the U.S. waterways (Clark, 1987).

Only a portion of the above is due strictly to agricultural soil erosion. OMAF found that cropland erosion was responsible for about 25 percent of total phosphorus loads (Coote, 1980). B[illegible] *et al.*, in a 1989 study, found that 50% of total annual phosphorus loads to Southwestern Ontario reservoirs was due to agricultural soil erosion. A large portion (one-third) of annual pollution loads can also be attributed to continuous low-flow sources such as milkhouse and industrial waste effluent.

The off-site damages from water-induced soil erosion have not been explicitly treated by some stakeholders (e.g., farmers, government) as a cost of production because the negative affects of erosion to downstream activities do not directly influence farming practices. One of the major conditions required for the adoption of conservation practices is proof that recommended

technologies are efficient and cost-effective (Smithers and Smit, 1989). Due to the lack of awareness and information regarding the environmental and economic impact of erosion on downstream activities, farmers may not be aware of the extent of the impact; or how they may benefit from adopting such practices.

Failure to account for off-site damages leads to under-investment in soil conservation. An evaluation of both on-farm financial impacts and off-farm financial impacts will indicate, as closely as possible, the true cost of erosion. This evaluation which deals strictly with off-farm impact, should therefore form a basis for enforcing proper conservation techniques. Increased awareness of these off-site damages may provide farmers, government and the public with a better sense of true damages of agricultural erosion.

Basic to the understanding of water pollution that originates from agricultural erosion, are the general water quality criteria outlined by the Ministry of the Environment. There are five general conditions which should be met as proposed by the Ministry of the Environment. Basically, all water shall be free from substances attributable to human related point sources or non-point source discharge in concentrations that (MOE, 1984):

1. Settle as objectionable deposits;
2. Float as debris, scum, oil and other matter to form nuisances;
3. Produce objectionable colour, odour, taste or turbidity;
4. Injure, are toxic to or produce adverse physiological or behaviour responses in humans, animals or plants; and
5. Produce undesirable aquatic life or result in the dominance of nuisance species.

The fourth criteria relates specifically to pesticides. Prior to 1980 very few reliable tests were available to indicate the level of toxic chemicals in the Great Lakes waters. Since 1980, guidelines have been established for specific chemicals that have been found to exist in harmful quantities in streams and rivers (i.e., aldrin/dieldrin, chlordane, DDT, endrin etc). Open water is generally

less polluted than the near shore waters of harbours, streams and connecting channels (Environment Canada *et al.*, 1991). Once in receiving waters, contaminants react chemically and biologically with their environment making them difficult to measure (Clark *et al.*, 1985). Consequently, it is difficult to generalize about the overall effects of contaminants on receiving waters.

However, in order to analyze the relationships between off-farm activities and in-stream sediment, phosphorus and pesticide loads, it is necessary to describe and define the processes that underlie the analysis so as to understand the linkages that may exist between individual activities and erosion processes. The definitions explained below relate to those factors that are most relevant to this study, including sediment and phosphorus transport, eutrophication and pesticides in receiving waters. These are discussed in the following sections.

3.4 SEDIMENT

In this section focusing on sediment, the processes of sediment transport, sediment as a pollutant and turbidity are discussed.

3.4.1 Sediment Transport within a Waterway

"Sediment" is defined as the deposit of material following suspension and transport by water. Sediment material is composed of organic matter from erosion, aquatic or riparian plant growth or inorganic material (i.e. rocks) which almost exclusively originates with the erosion process.

The fate of sediment in receiving waters is defined as the changes in the substance after it enters the stream (Whipple, 1977). Fine particles (particularly silt and clay) may be carried indefinitely by a streams current as suspended sediment, but the heavier sediment particles soon descend to the bed of the stream, to make up the bed load. The heavy particles remain in

place awaiting the next high water or they move intermittently along the stream bottom producing an unstable substrate, unsuitable for bottom dwellers.

The bed load consists of material on the top layer of the river's bed. This material is continually and slowly carried downstream. Constant bumping and sliding wears the particles down, therefore, the size of the bed load material tends to decrease as it reaches the mouth. Rivers become less steep as they approach their mouths, allowing for slower water velocity and a decrease in bed load movement.

The amount of suspended sediment carried will increase with quantity, depth and most importantly velocity of the rivers water. During floods, great amounts of sediment transport to and within rivers occurs. Consequently, fast moving bodies of water typically carry more sediment.

Therefore, the efficiency of sediment transport in a channel varies directly with the average flow velocity in the channel and inversely with the fall velocity of the entrained sediment (Dickinson *et al.*, 1986). The length of the flow path and the physical characteristics of the entrained sediment are also prime factors in determining how sediment is delivered. Once sediment enters a waterway, one of the most important factors determining the magnitude and location of downstream impacts is how quickly it is redeposited (Clark *et al.*, 1985). Huge quantities of suspended sediments in a stream are reduced in quantity in passing downstream. On the average, a small river basin (1000 square miles) discharges from its lower end 10-20% of the sediment poured into it (Whipple, 1977). The sediment that is not discharged forms part of the stream or the river bed.

However, a number of studies (Rudha *et al.*, 1986 and Dickinson *et al.*, 1986) suggest that sediment transport processes are variable. For example, in the Canadian Great Lakes basin it was observed that more than three-quarters of the total annual sediment loads from selected rivers enter the lakes in a 2 to 3 month period during late winter and early spring. The previously mentioned studies also reveal that a large proportion (67 - 82%) of the spring sediment

loads originate from a small percentage of the watershed (14 - 16%). For example, about 78 percent of the Canangigique West watershed area in the Grand River basin exhibits sediment yield rates less than the accepted spring limits of 1 t ha^{-1}. The remaining 12% of the watershed displayed sediment yields much greater than the accepted spring level. Average sediment yields for the Canangigique watershed were 0.82 t ha^{-1}, although they ranged as high as 16.8 t ha^{-1} (during spring run-off in sub-basins with very high amounts of sediment entering receiving waters).

3.4.2 Sediment as a Pollutant

As sediment travels through a watershed it may be considered a pollutant when it renders water unfit for a particular use either by its presence in suspension or as deposit on the bottom (So *et al.*, 1982). For example, settled sediment can cause serious problems for aquatic life by covering food sources, hiding places and nesting sites. It can also clog navigation channels, reduce the capacities of stream channels and reservoirs, and extensively change a waterway's structure and ecology.

Another major significant characteristic of sediment as a pollutant is related to its ability to serve as a vehicle to carry other pollutants such as nutrients, pesticides, trace organics and heavy metals into receiving waters.

3.4.3 Turbidity

Turbidity is another important factor that is to be investigated in this study. Turbidity is caused by the suspension of materials (e.g., sediment, algae and bacteria) which prevent the penetration of sunlight in a water body. Consequently, turbidity decreases transparency.

Turbidity is measured by passing a beam of light through a water sample and measuring the amount of light scattered at 90 degrees to the original beam

(Holmes, 1986). This is reported in Nephelometric Turbidity Units (NTU). Jackson Turbidity Units (JTU) - with a low value of 25 units in comparison, is a visual method to measure the length of a light path through a water sample.

Suspended sediment particles reflect and absorb light, preventing sunlight from penetrating the deeper layers of water. An increase in temperature stratification (top layers of water will be warmer than those deeper down and therefore more oxygen rich) occurs as turbidity levels increase which means that the normal mixing of oxygen rich surface waters with those deeper down is prohibited especially for slower moving streams (Clark *et al.*, 1985). Further complications to oxygenated water occurs as algae and other organic matter decompose. As the decomposed matter sink downward, they deplete what dissolved oxygen remains in the lower layers due to lack of mixing. As oxygen levels deplete, the water environment becomes less able to support the life of any oxygen dependent organism (e.g., fish and plankton).

Turbid waters also exhibit shallow "euphotic" zones - the depth at which sufficient light exists for photosynthesis. The higher the turbidity level of the water body, the less light penetration. Turbid water interferes with the primary production of green plants and organic matter below this zone. As the euphotic zone becomes smaller and smaller, primary production also decreases. A reduction in aquatic plants can have direct effects on the entire aquatic ecosystem.

3.5 PHOSPHORUS

In this section, a discussion is provided on phosphorus movement, phosphorus as a pollutant and the process of eutrophication. The reason for concern over excessive phosphorus loads becomes evident as its effects are explained.

3.5.1 Phosphorus and Phosphorus Transport

Another equally important component of soil erosion is phosphorus loading from agricultural sources. OMAF found that cropland erosion was responsible for about 25 percent of the total phosphorus loads to the Great Lakes in 1976 (Coote, 1980). Bos *et al.*, found it to be 50% for selected Southwestern Ontario watersheds.

Phosphorus is a significant growth-limiting factor in most agricultural and marine production (Kormondy, 1984; IJC, 1980). The Grand River basin, for example has been found to be deficient in organic matter and phosphates. The reason being, that the amount of phosphorus compared to other elements (i.e., nitrogen) in an organism is far greater than the amount of phosphorus available to plants through the soil. Only a small portion of phosphorus applied to fields is utilized for crop growth. Much of the phosphorus added to the soil does not stay in solution but is adsorbed (held onto the surface) by soil particles. For example, a study by Dickinson *et al.*, 1988, found that on average only 10 percent of soil phosphorus was being used by plants. According to Clark, 1985 the remaining phosphorus, not used for crop growth will:

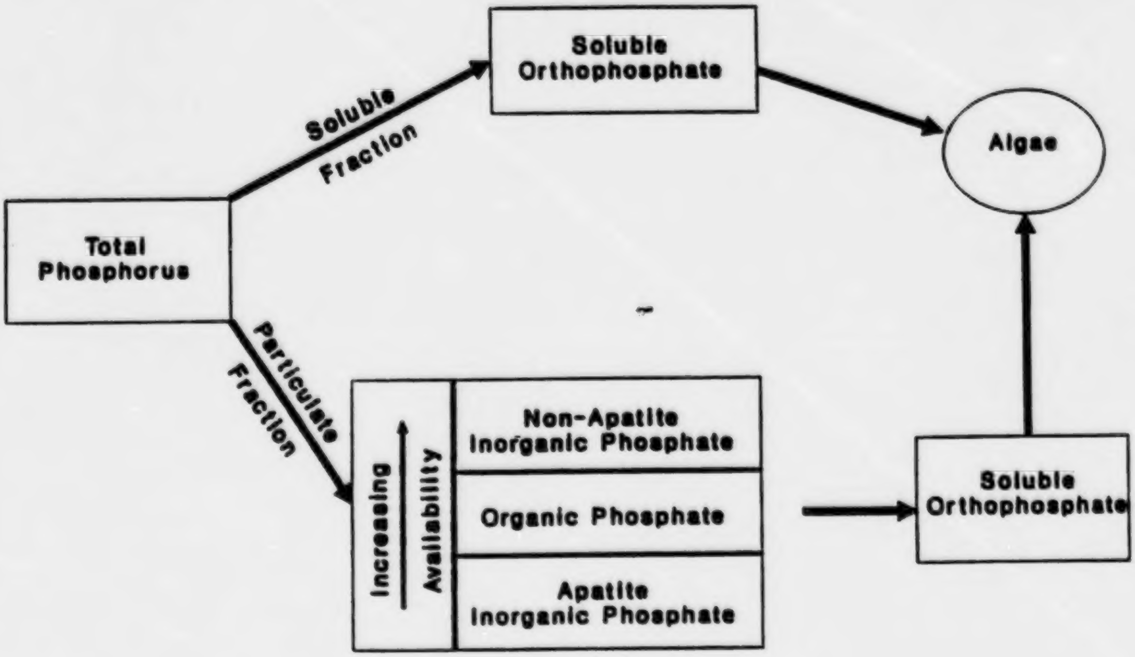
1) bind with the soil - which is either available for later crop growth or is transported (carried off) with the eroding soil;

2) dissolve in the soil's water system (tile drains or groundwater); or

3) run-off as surface water in a suspended or dissolved form.

The majority of the phosphorus that becomes part of the erosion process, is insoluble phosphorus, held by sediment particles. Figure 3.1 explains the complex flow of phosphorus.

Figure 3.1 General Relationships Between Phosphorus Forms and Algae



Note: (This is not a complete nutrient cycle diagram - rather a schematic showing the paths between total phosphorus inputs & algae.)

Source: IJC, Phosphorus Management for the Great Lakes, Final Report for the Phosphorus Management Strategies Task Force.

Generally, 40 percent of the phosphorus found on soil particles (adsorbed or labile) is exchangeable (Dickinson *et al.*, 1988). Therefore, as the adsorbed phosphorus is in contact with water, it reacts with dissolved inorganic phosphorus until equilibrium is established, and becomes available as a source of algae and aquatic plants.

Because of the ability of phosphorus to enhance plant growth and thus possibly increase yields, additions of phosphorus for agricultural purposes have become a very common agricultural practice to increase available nutrients. Such additions to agricultural soil will nevertheless, also increase the amount of phosphorus found in eroded material and ultimately that reaching the waterways. As a result of farm fertilization practices and household detergent use, phosphorus levels in Ontario waterways have generally become far too high, enhancing primary aquatic plant growth.

3.5.2 Phosphorus as a Pollutant

Phosphorus from non-point sources, according to Ribaudo (1988), is any phosphorus whose specific source cannot be identified, such as run-off from agricultural land. Non-point sources which originate from rural watersheds have been estimated to be between 60 and 80 percent particulate and 20 to 40 percent water-soluble (Clark *et al.*, 1985; Gregor, 1980; MOE and Huber, 1982). This indicates that 60 percent of phosphorus pollution is bound to sediment and the remaining 40 percent of phosphorus is water soluble. Accordingly, sediment is the major transport vehicle for phosphorus (MOE, Dickson *et al.*, 1982).

As discussed earlier, a portion of the sediment bound phosphorus may later be used for plant growth through the process of desorption (i.e., when phosphorus is released into solution for absorption, depending on the concentration in the surrounding water). This will occur only when soluble phosphorus concentrations are low, and adsorbed (labile) phosphorus is readily available (Kormondy, 1988).

As more phosphorus becomes biologically available for the growth and uptake by algae plants, the population of algae continue to increase. As algae utilize the readily available phosphorus, enough replacement phosphorus is released from sediment bound particles to maintain a concentration sufficient for continual algae growth. The productivity (ability to support plant life) of the stream in turn will affect the amount of phosphorus delivered to the lake. Therefore as productivity increases upstream, utilizing available phosphorus, less phosphorus is delivered further downstream.

Typical phosphorus loads for the agricultural watersheds and for the sub-basins of the Grand and Saugeen River Basin are as follows. It was estimated that about 70% of the agricultural contribution of total phosphorus in the above mentioned watersheds could be attributed to run-off from cropland, 20% to livestock operations, 5% to stream bank erosion and 5% to other (Gregor *et al.*, 1980). Extrapolation to the Grand and Saugeen River Basins using the regression equation also indicated that 50% to 70% of the total phosphorus load in these rivers could be attributed to agricultural activities.

The PLUARG studies in 1976-1977 found that agricultural areas contributed 64.5% of total phosphorus loads and 83.5% of suspended sediment loads. Urban areas contributed 24.8% and 0.1% respectively to phosphorus and sediment loads.

There are, however, general guidelines, although site-specific studies give greater insight into the problems of excessive phosphorus loadings. For example, MOE has found that to avoid excessive algae growth, total average phosphorus loads should not exceed 20 μg/L, and to maintain aesthetic quality in lakes, total phosphorus during ice-free periods should not exceed 10 μg/L in lakes or 30 μg/L in rivers (MOE, 1984).

3.5.3 Eutrophication

Eutrophication is the excessive nutrient enrichment of a body of water so that high rates of biological activity are stimulated. The process of eutrophication is directly related to the process of excessive phosphorus loading of water sources. Excessive phosphorus loads commonly lead to abundant algae growth. As algae plants die and decompose, they create a rich food source for bacteria (which assist in decomposition). As bacteria speed up the decomposition process, oxygen required by aquatic organisms is depleted from the surrounding water. In its natural state, a water body usually contains inadequate amounts of one or two nutrients for the water to sustain its maximum possible plant growth. Phosphorus being a limiting nutrient, is therefore, the major cause of excessive eutrophication of lakes as run-off from agricultural fertilizer use increases.

Eutrophication is one of the most serious water-quality problems facing the U.S. (IJC and Anon, 1969). According to the Phosphorus Management Committee for the Great Lakes, increases in nutrient concentrations and decreases in dissolved-oxygen content are acceptable indices of eutrophication.

The problems of eutrophication can be further enhanced by shallow water bodies, and increased water temperature. The resultant effects of eutrophication are undesirable changes in the water's colour, taste, and odour. Increased concentrations of iron and manganese compounds in the water also occur as decomposing algae continue to satisfy the oxygen needs by reducing oxides in settled sediment.

A 10 percent reduction in sediment yield at the stream due to conservation practices will not directly correspond to a 10 percent decrease in phosphorus loading. Since only about 60 percent of the phosphorus is bound to sediment the reduction in phosphorus loadings are in the area 6%. The remaining 40 percent of the phosphorus load which is water soluble will always remain as a constant flow from the point of erosion until it reaches a waterway.

3.6 PESTICIDES

This section on pesticides discusses the transportation of pesticides, their impact on fish and drinking water, and the role of pesticides in this analysis.

3.6.1 Transportation of Pesticides

Pesticide compounds that enter the water basin, may be:

a) suspended as distinct particles;
b) chemically bound to sediment particles; and/or
c) dissolved.

The biological availability of a pesticide (measured in parts per billion or parts per trillion) is determined by the type of pesticide, and the sediment it is attached to. Pesticides may be taken up by the biota, be deposited in the sediments at the bottom of the lake, or be vaporized into the atmosphere. Toxic chemicals can also enter lake systems by air deposition. For example, it has been reported that pesticides are being transported for many thousands of miles and then found to be precipitating into the Great Lakes due to their vast surface areas (Environment Canada *et al.*, 1991).

However, the potential properties of pesticides once they reach the water can be somewhat confusing. For instance, low water soluble pesticides are fat (lipid) soluble, and as such are not readily excreted once ingested. They can persist within the aquatic environment for long periods of time (months to years), travelling downstream, contaminating fish and plant habitats. The longer the pesticide remains in the environment without degrading, the greater the potential for harm to aquatic life. Fat soluble pesticides accumulate in the fatty tissues of fish, animals and humans until toxic levels are reached. Organochlorines (OCs) such as DDT, aldrin/dieldrin, heptachlor, chlordane and toxaphene are examples of low water soluble pesticides (Clark *et al.*, 1985).

The extent of their toxicity has been realized, and most have been banned from use.

Organophosphates (OPs) (e.g., fonofos, terbufos, malathion, diazinon, and Guthion etc.), unlike OCs tend to be relatively soluble, and are therefore found in solution. Generally, OPs degrade very quickly. However, studies have revealed that certain organophosphate insecticides (ie. ethion) are more insoluble then once thought, therefore they can be absorbed by sediment and eventually incorporated into the bed material - allowing for greater persistence in the aquatic environment (Miles *et al.*, 1978, and Sharon *et al.*, 1980). In a 1973 study by Miles and Harris, they found that peak concentrations for all insecticides occurred during spring run-off with subsequent levelling off. As well, they found that concentrations of OC insecticides (or other insoluble pesticides) in bottom muck are much higher than those found in the surrounding water. On the other hand, concentrations of DDT and dieldrin are smaller in sediment loads than in water samples, which is consistent with the solubility of these chemicals (Miles, 1976).

Depending on the site, the main sources of pesticide pollution can include any of the following, cropland, urban run-off, forest and pasture land run-off, accidental spills, careless disposal, and hazardous waste dumps. Frank (1986) feels that spills and carelessness are the leading causes for the levels of pesticide found in water. Therefore, much of the contamination occurring could be avoided by better storage, handling, mixing and dispensing of pesticides. Even though pesticides carried by storm events and tile drains cannot be avoided, these sources of pollution can be considered minor if the pesticide breaks down within the same growing season. However, pesticides like atrazine (triazine herbicide) persist from one season to the next and can thus be found in water at all times.

Several factors determine the amount of a pesticide that is transported. Firstly, the period of time between application and the next significant rainfall is very important. U.S. studies found that the annual loss of pesticides from agricultural fields was 0.5% or less unless a severe rainfall occurred within one

to two weeks of application. Annual losses would increase to approximately 6% under heavy rainfall conditions (Clark *et al.*, 1985).

Secondly, the form in which a pesticide is applied to the field can affect transport. Solids or powders are easily dislodged from soil surfaces by rain. Liquids on the other hand, adhere to plants or soils and are therefore less readily eroded away. Chemical and physical properties also affect the amount of contaminant transported. Chlorinated hydrocarbons and insoluble pesticides are usually transported on soil particles rather than dissolved in water. The probable method of pesticide transport for insoluble (e.g., organochlorines) pesticides is with eroded soil. However, there has been increased use of more soluble OP and increased growth in use of soluble herbicides. This has caused an increase in pesticide concentrations in run-off (not erosion) resulting in soluble pesticides being the predominant cause of pesticide contamination of surface waters.

A pesticide's mobility is also influenced by its tendency to be adsorbed by soil and to decompose. The longer a pesticide persists before decomposing, the more of it is available for transport during successive rainfalls. Many of the newer pesticides (carbamate and organophosphate insecticides) can break down within weeks or days into nontoxic components, even though they are very toxic when applied. Organochlorines, on the other hand, take years to break down into nontoxic compounds. For example, DDT takes 11 years for a 95% breakdown, dieldrin 9.7 years, and chlordane 4.2 years. If the newer, shorter-lived pesticides (carbofuran) decompose before they are transported far from their application site, environmental damage probably will be fairly localized.

As mentioned earlier, the chemical composition of the soil influences the extent to which a pesticide is adsorbed and immobilized. The adsorption potential of soils high in organic matter may be 10 to 1,000 times greater than that of inorganic soils. Therefore, inorganic soils yield less pesticide to run-off. In a waterway, the concentration of dissolved pesticides can be decreased if the suspended or deposited sediments have a high organic content and are, thus,

able to adsorb the pesticides. Because adsorption is reversible, some pesticides transported from a field primarily by sediment will, upon reaching surface waters, desorb and be carried off in solution.

3.6.2 Effect of Pesticides on Fish

There has been a general trend towards diminishing commercial fish harvests in the Great Lakes since 1930. Presently, lake trout populations in the Great Lakes are maintained by intensive stocking programs and their is evidence of poor recruitment of young fish into the breeding population (Environment Canada *et al.*, 1991). The effect of chemicals on fish populations are often marked by the effects of non-chemical stresses and organisms may die before the effects of chemical exposure are observed. Mortalities of lake trout (and coho salmon) fry were first reported in Lake Michigan in 1969. Lake trout were studied for 12 years and researchers concluded that chemicals have been involved in the reproductive impairment of Lake Michigan trout because a) the most heavily contaminated area of the lake was the location for fish culls, and because b) mortality occurred during the "swim-up" stage of life when the trout fry are the most sensitive to chemical exposure (Clark *et al.*, 1985).

Today, an approach has now been developed in fish and wildlife toxicology to detect changes induced in fish cells as a result of exposure to chemicals in the environment, called biomarkers. In fish, two enzymes (mixed function oxidase and amino levulinic acid dehydratase) found in all species are used to assess health, and to help indicate what ill effects (e.g., deformitis, reproductive problems) the chemicals may have on the fish themselves and the resulting implications for humans.

"The biomagnification of contaminants through successive levels of the food web can make fish unsuitable for human or wildlife consumption," (Environment Canada *et al.*, pp.18). Fish with higher lipid (fat) content will have greater concentrations of organochlorine contaminants in its tissues. Salmon, trout, carp and catfish have been found to exhibit relatively higher

levels of organochlorine contaminant levels than low lipid species such as walleye, northern pike and yellow perch. Older fish that have more lipids than younger fish have also been exposed to contaminants for a longer period of time, thus having higher concentrations. The Guide to Eating Ontario Sport Fish, list and advise fishers on the frequency and amount of consumption recommended based on species type and its size and the frequency of consumption. Children and women of childbearing age are to eat only those fish with absolutely no restrictions attached.

Table 3.1 indicates fish consumption criteria for the protection of consumers of fish. In Canada, the Department of Fisheries and Oceans fish inspection programs ensures that contaminant levels in fish species caught commercially in the Great Lakes, and processed in registered fish processing facilities do not exceed guidelines set by Health and Welfare Canada. The maximum consumption quantities given in the Guide to Eating Ontario Sport Fish are also shown although they are normally expressed in number of meals and total weight per week. These values are developed to determine the tolerable daily intake (TDI) or the allowable quantity to be consumed on a daily basis, over a lifetime. Safety factors are included when fish consumption guidelines are established because of the uncertainties about exposure to contaminants and the resulting effects.

Table 3.1 Fish Consumption Criteria[1] (Parts Per Million, Wet Weight Except Dioxin, Parts per Trillion Wet Weight)

Parameter	Health & Welfare Canada Regulatory Limit[2]	Ontario Sport Fish Consumption Guideline[3]
Aldrin/Dieldrin	0.1	--
DDT (total)	5.0	5.0
Dioxin (2,3,7,8-TCDD)	20.0 (ppt)	20.0 (ppt)
Endrin	0.1	--
Heptachlor/Epoxide	0.1	--
Hexachlorobenzene (HCB)	0.1	--

1. Criteria based on skinless fillet unless otherwise footnoted.
2. HWC regulatory limits apply to fish in commerce only. The Province of Ontario applies these guidelines to sport fish consumption.
3. Ontario guidelines refer to restricted frequency of consumption of fish: If level of a single contaminant in a skinless dorsal fillet is below the guideline then unrestricted consumption is allowed; if the level exceeds the guideline then restriction in frequency of fish meals is advised. For women of child-bearing age and children under 15 years, restrictions apply below the guideline levels and no consumption is recommended for levels that exceed the guideline.

Source: Environment Canada *et al.*, 1991

3.6.3 Impact on Drinking Water

Most contaminants found in drinking water are found at very low concentrations and are well below current Canadian drinking water guidelines. The water quality objectives pertaining to the quantity of toxic organic chemicals in the Great Lakes are presented in Table 3.2. On average, fewer than 1% of the samples analyzed by the Province of Ontario have detectable levels of the most common environmental organic contaminants (Environment Canada *et al.*, 1991). Contaminant levels in municipal water occasionally may exceed guidelines. However, this does not imply that drinking water is dangerous to human health since guidelines are based on lifetime exposures and have been developed with wide safety margins. When samples taken continually exceed the guidelines, they serve as an alert that there may be an uncontrolled source of a particular chemical.

For those contaminants considered toxic for which there have been no limits set, the concentrations of such compounds in water or aquatic organisms should be less than detection levels as determined by the best scientific method available (i.e., 0.005 ppb).

Table 3.2 Water Quality Objectives of Persistent Toxic Organic Chemicals in the Great Lakes

Substance	Water Quality Objective[1] (parts per billion)
Aldrin/dieldrin	0.001
Benzo[a]pyrene	0.01
Chlordane	0.06
DDT	0.003
Endrin	0.002
Heptachlor	0.001
Lindane	0.01
Methoxychlor	0.04
Mirex	0.005[2]
PCP (pentachlorophenol)	0.4
DEHP (Di-2-ethylhexylphthalate)	0.6
PCBs (polychlorinated biphenyls)	0.001 (proposed)
Toxaphene	0.008
2,3,7,8-TCDD (a dioxin congener)	0.00001 (detection limit)

1. As stated in the 1978 Great Lakes Quality Agreement or subsequently proposed. Levels are set to protect the most sensitive user (not always humans).

2. Objectives for mirex is "substantially absent" or below the level of detection as determined by the best methodology (presently 0.005 ppb).

Source: Environment Canada *et al.*, 1991.

3.6.4 Inclusion/Exclusion of Pesticides in Downstream Impact Areas

Presently, levels of contaminants in Great Lakes fish have decreased substantially from the high vales reported in the 1970s. The Great Lakes support the largest freshwater fishery in the world (Env. Canada *et al.*, 1991). As a result of toxic contaminants, a number of commercial fisheries have been closed in all of the Great Lakes. Since 1980, a number of closed fisheries have been reopened. However, contaminant related restrictions on harvest are still in place for many commercial fish species.

The effects of agricultural contaminants on fish populations are difficult to separate from the effects of other contaminants, overfishing, habitat loss and the introduction of exotic species. Therefore, although we may know how pesticides effect fish, it may be difficult to relate a value or figure to impacts on the commercial fishing industry. As data becomes available, this task may become relatively easier and we may find that pesticides do indeed impact upon commercial fish to a significant extent.

As for the effect of pesticides on sport fishing, it is difficult to measure because most of the pleasure derived from the recreational experience itself comes from the catch not from the eating the fish. According to the Ontario Sport Fishing Survey, a number of factors influence the overall enjoyment of this sport. The environment was listed as the most important factor, followed by the quality of the water, natural beauty of the province, and favourable weather conditions. Anglers attached very little importance to catching fish as a source of food.

Serious fishers, who intend to eat the fish they catch are referred to the *Guide to Eating Ontario Sport Fish* which verbally and visually explains which fish should or should not be eaten. The group of fishers who may be concerned about the consumption of wild fish they eat are Native fishers. According to Ted Cowan of the Department of Fisheries and Oceans, only a small number (approximately 15,000) of Ontario natives have a heavy reliance on wild food including fish. The average consumption of individuals with a high reliance on

fish is about 50 - 60 lbs per year compared to 10 - 12 lbs for the average consumer. For a few people, who are "intensive" fishers, their yearly consumption can be as high as 100 lbs per year. However, "intensive" fishers would normally be located in Northwestern Ontario where forestry and mining would contribute to most if not all of any chemical contaminations found. The effect of pesticides from agricultural contaminants would be marginal.

The impact of pesticides on water treatment facilities is yet unknown.

4.0 PILOT DEMONSTRATION WATERSHED

In this section, aggregate levels for the macro-economic analysis are discussed. The emphasis being on the pilot demonstration watersheds; the level at which direct measurements will be obtained and eventually extrapolated to determine higher level analysis for later use.

4.1 AGGREGATION LEVELS FOR ANALYSIS

The magnitude of potential downstream and off-farm positive impacts increase as the number of fields and/or farms using conservation technology increases. This raises the issue of determining the level of aggregation for the macro-economic analysis. Figure 4.1 illustrates the various aggregate levels at which the impact analysis of conservation practices can be conducted.

Figure 4.1: Aggregation Level of Conservation Impact

1. Field Level
2. Farm Level
3. Sub-Watershed Level
4. Pilot Watershed Level
5. Larger Watershed Level
6. Regional Level
7. Provincial Level
8. National Level

Within SWEEP, a basin includes all of the area drained by its rivers and tributaries. A watershed is a line (usually a tributary) which separates the water flowing from tributaries to different rivers and basins. As an example, the Ninth watershed includes all the area drained by the Nith River, which is a subset of the Grand River basin. In the SWEEP project the control and the

treatment watersheds within the pilot watershed are referred to as sub-watersheds.

The SWEEP research objectives call for assessing impacts at the watershed community level. The pilot watersheds are defined as the Pilot Watershed Communities. As well, it is understood that aggregation and some impact analysis on watersheds that are larger than the pilot demonstration watersheds is expected. Consequently, some of the analysis will have to extrapolate the measured impact on the pilot watershed to a larger river watershed area. By doing so, the analysis may be subject to considerable error. However, the magnitude of impact will be larger than the error.

However, information on soil type, slope, existing practices, etc. are required across the watershed area in question, to adequately extrapolate the impact. The costs of such extrapolation and assignment of responsibility to qualified experts may constrain some portion of the analysis to remain at a pilot watershed level. Given the aggregation issues, the pilot watershed will be the first level of aggregation to assess the macro-economic impact.

4.2 CHARACTERISTICS OF THE PILOT WATERSHEDS

The pilot watersheds included in the SWEEP program are: Pittock; Kettle Creek; and Essex. Figures 4.2, 4.3 and 4.4 reveal all of the major river basins draining into the Great Lakes and corresponding regions and counties of the pilot demonstration watersheds. A major portion of the analysis will apply only to the control and participating sub-watersheds. Our analysis utilized case examples from previous studies to determine values for downstream impacts.

Figure 4.2 River Basins Draining into the Great Lakes

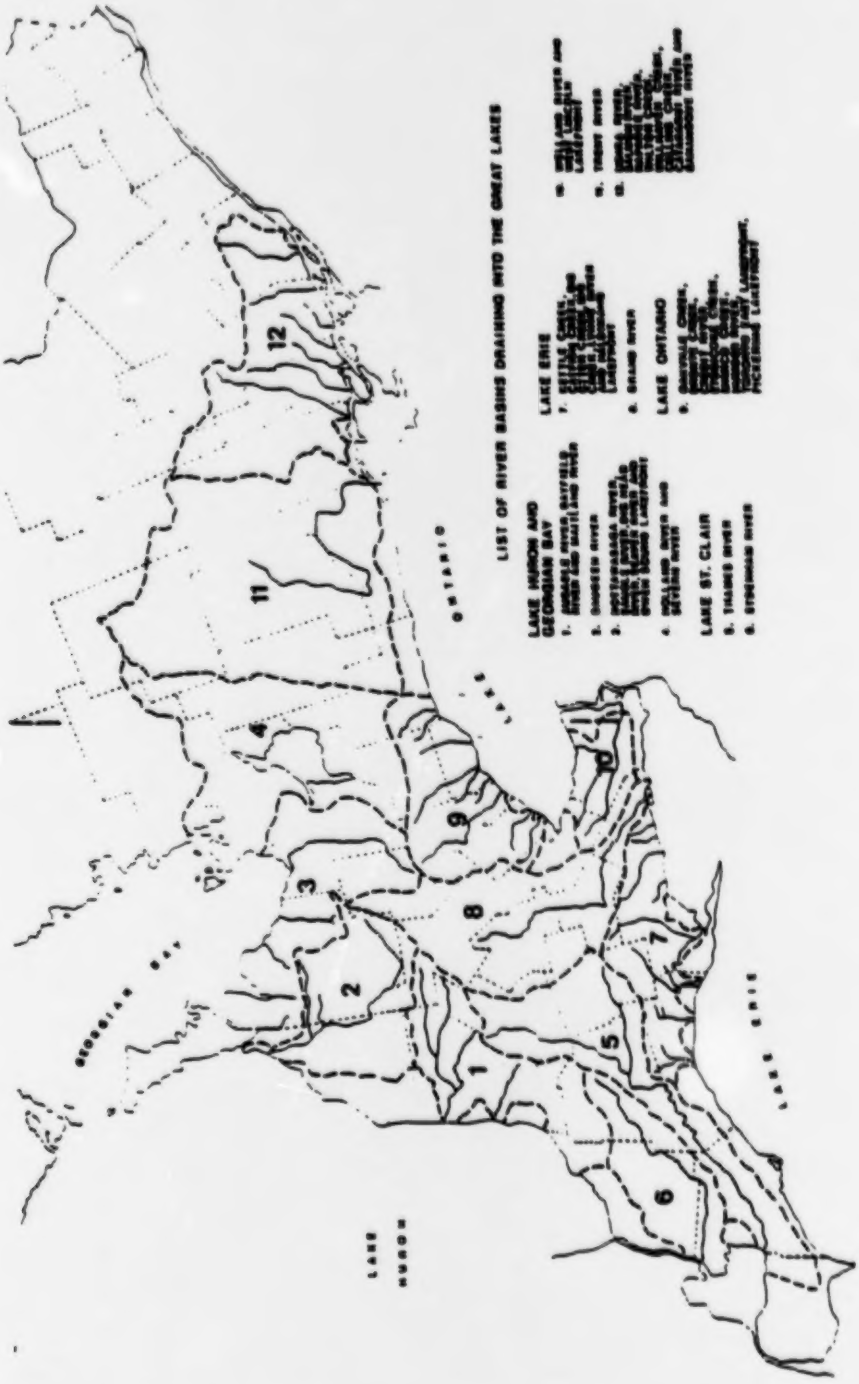


Figure 4.3 Ontario Map Showing Regions and Counties

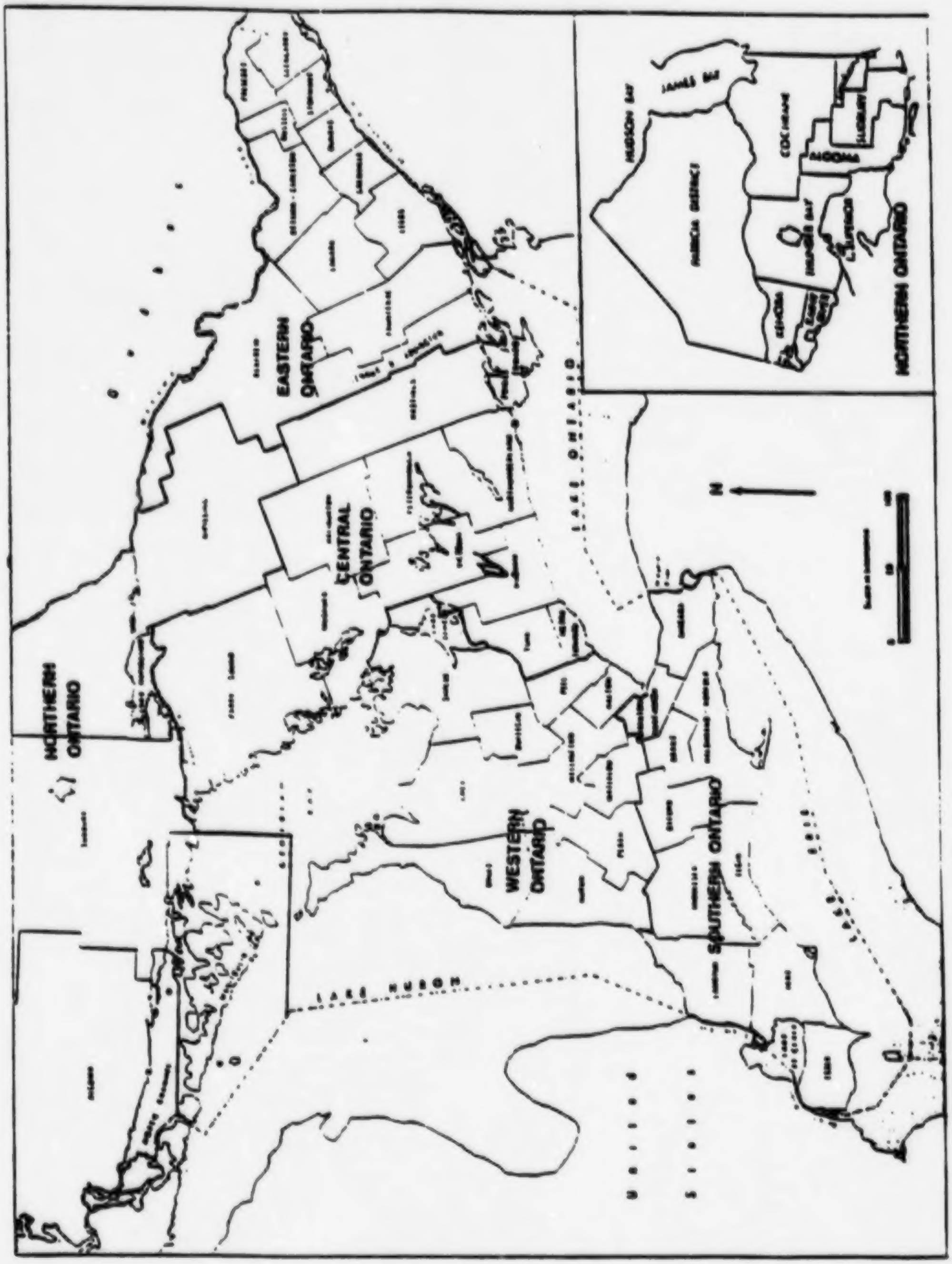
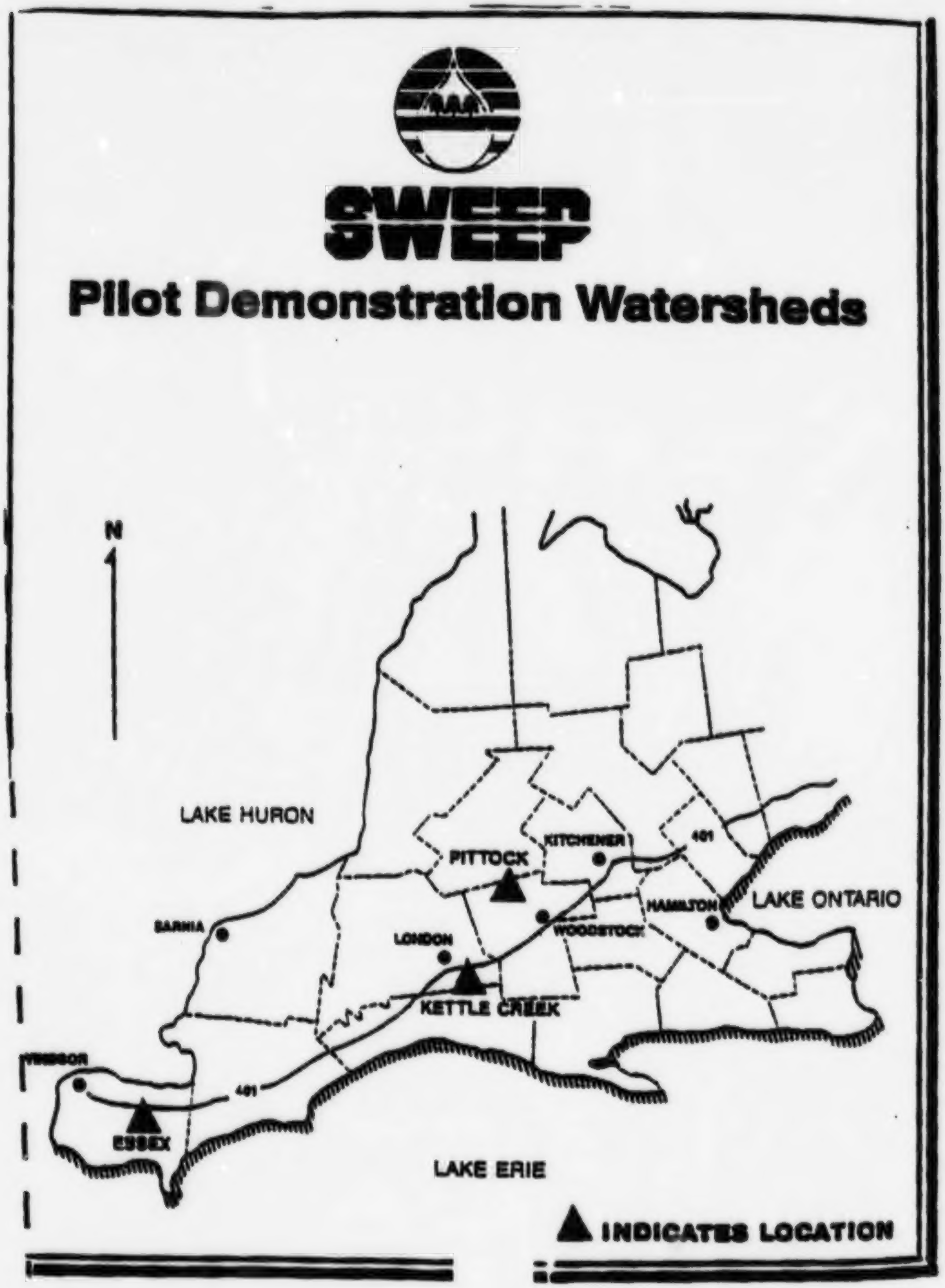


Figure 4.4 Pilot Demonstration Watersheds - Location



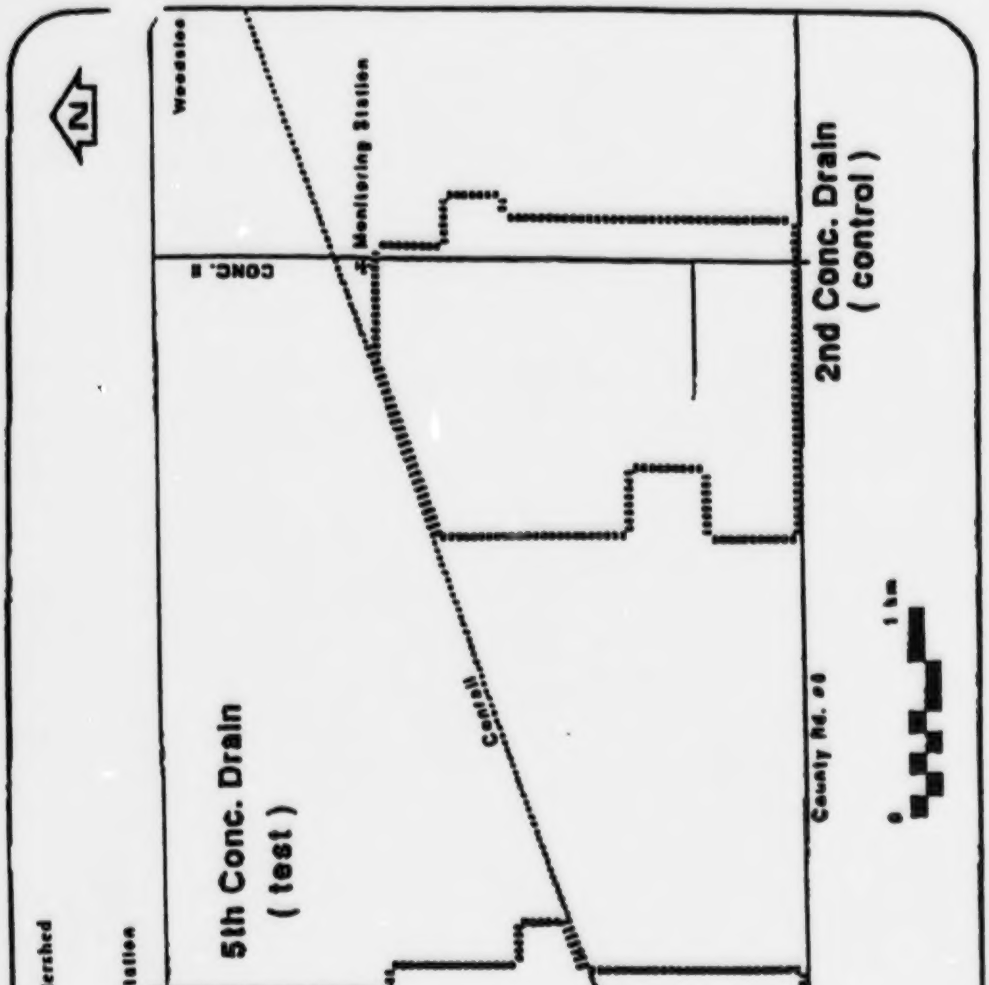
4.2.1 Essex Watershed

The Essex test watershed located just east of the town of Essex (see Figure 4.5), is 964 acres (390 hectares) in size, and the control watershed is 789 acres (319 hectares). Both Essex sub-watersheds are located on the extensive Brookston clay plain. The Brookston soil series types predominate in its clay and clay loam phase. Brookston clay is a poorly drained clay loam till material with numerous drainage problems which must be corrected with artificial drainage. The soil within the basin is recorded as primarily A-slopes (very flat). This indicates a low potential for erosion.

Within the sub-watersheds, there are 14 farms in the test watershed and 12 in the control. Farm size ranges from a low of 30 acres to a high of 1400 acres. No farmer works land in both watershed areas.

By the end of the basin selection process only one farmer in the control area had declined to participate in the conservation program, but he had expressed some interest in learning about the program. All enterprises in the Essex study areas are cash crops, with the exception of one farmer growing hay in the control watershed to support his dairy operation elsewhere. The main crop rotation is a grain-corn-soybean combination. Tillage practices are primarily conventional (primarily mouldboard plough), and no unique problems in these areas were noted by farmers.

Figure 4.5 Essex Pilot Watershed



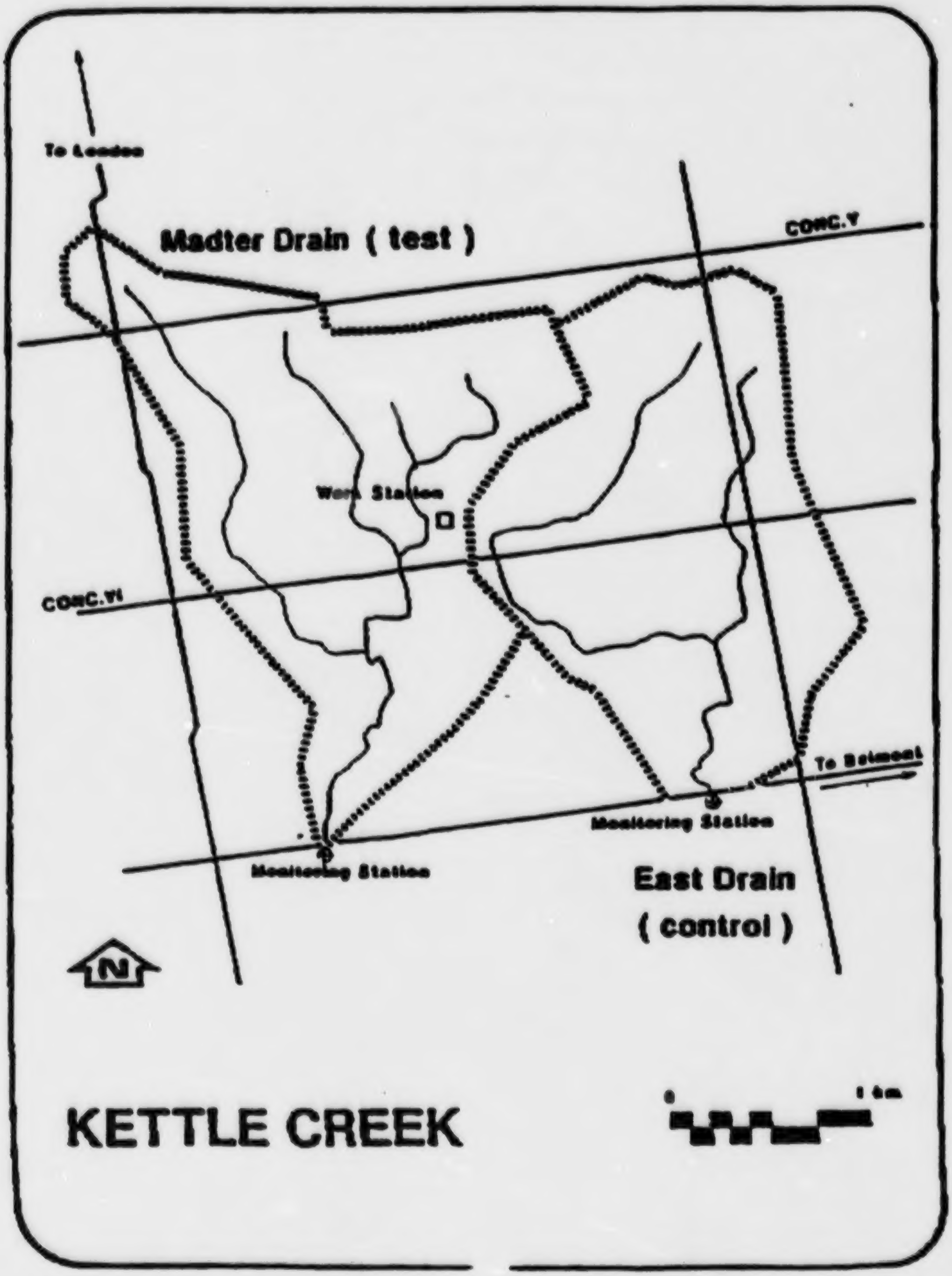
4.2.2 Kettle Creek Watershed

The Kettle Creek pilot watershed is located south of London (see Figure 4.6). The Kettle test area is 988 acres (400 hectares), while the control area is 783 acres or 317 hectares. It appears that the most prominent soil in this basin is Gobles loamy phase clay loam. Significant amounts of Tavistock silt loam, Muriel loamy phase clay loam and Tuscola silt loam are also present. Gobles and Muriel are both clay loam till, but Gobles is imperfectly drained while Muriel is well drained. Tavistock and Tuscola are both imperfectly drained and are more susceptible to erosion due to their higher proportion of silt which erodes more readily than clay.

The slope class in Kettle Creek also adds to the erosivity of the landscape. The topography is much steeper and changeable than in the other basins. Patterns of previous erosion are also more pronounced throughout this basin.

Land use characteristics of Kettle indicate that there are 14 farms in the test watershed and 10 in the control. Farm sizes range from a high of 170 acres to a low of 20 acres. The largest farm operated entirely within the test area is approximately 170 acres and within the control area 150 acres. Unlike Essex, Kettle has some poultry and one dairy operation. The main crop rotation is a corn-soybean-grain combination. The mouldboard plough remains the primary tillage tool, although the chisel plough is used in combination with the mouldboard by one-third of the farm operators. Conventional fertilizer, herbicide and pesticide practices are used.

Figure 4.6 Kettle Creek Pilot Watershed



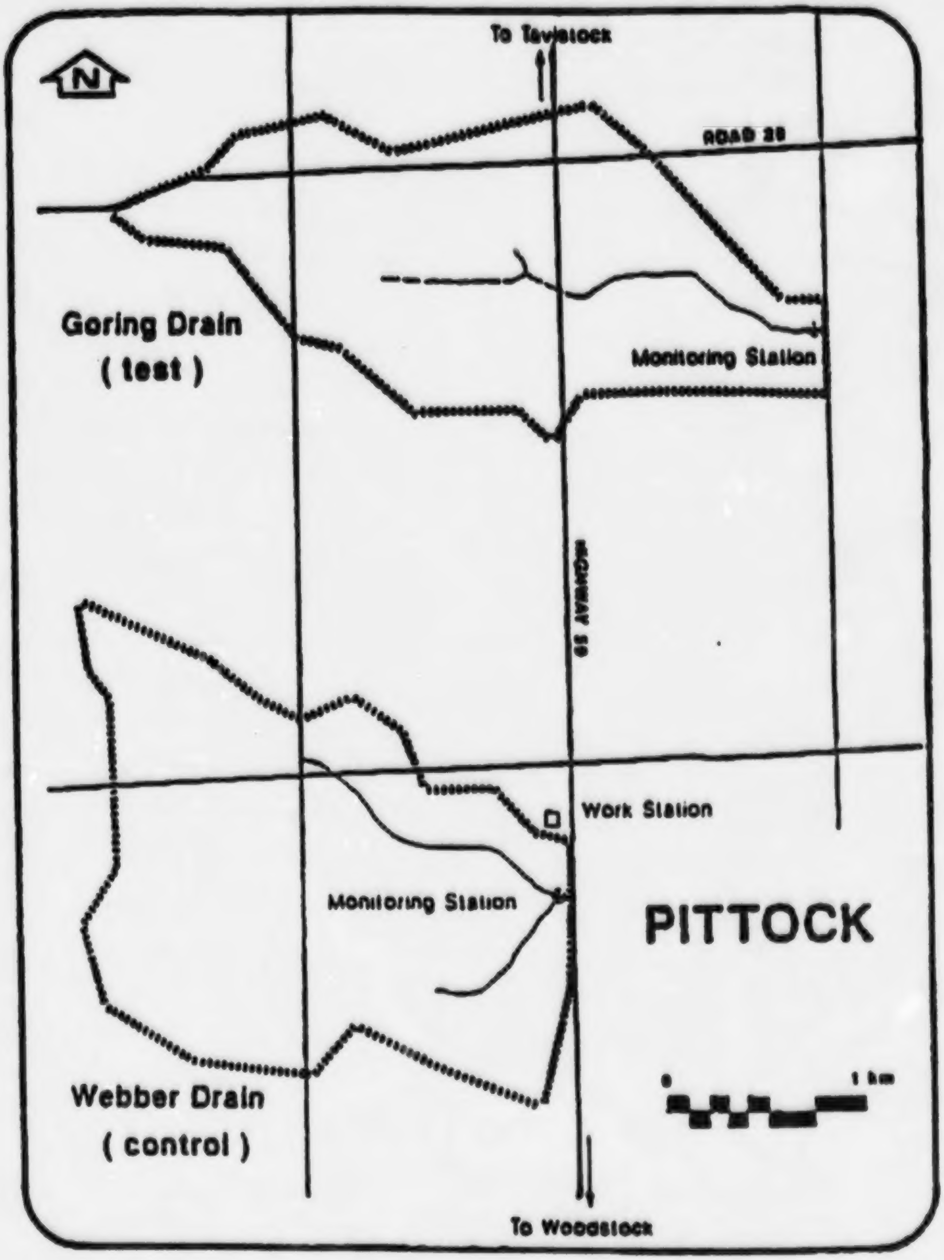
4.2.3 Pittock Watershed

The Pittock test watershed found on Highway 59 between Tavistock and Woodstock (see Figure 4.7) is 878 acres (355 hectares) in size, while the control watershed is 908 acres (367 hectares). The most prominent soil in the basin is the Embro silt loam with large areas of Colwood silt loam. These soils have silt loam tops and are therefore, susceptible to soil erosion due to cultivation practices. Another important factor in the susceptibility of soils is the slope class which refers to the various inclinations on farm land. For example, a horizontal surface or one inclined at an angle of less than 2 degrees is considered flat (no class value) while a surface that is inclined between 2 and 40 degrees is a slope with a class value. The greater the slope the more erosion is likely to occur. The majority of Embro soils are class A, referred to as having the least erodible soil of all soil classes.

Within the sub-watersheds, there are 14 farms in the test watershed and 15 in the control watershed. Within the control, there are two farmers who have refused to participate in the pilot watershed demonstrations (PWD). In the test there is one farmer who is willing to participate but unwilling to keep records.

Farm sizes range from a low of 30 acres to a high of 1700 acres. The Pittock area is dominated by livestock operations, while the main crop rotation is a corn-bean-grain-hay combination on the livestock farms, and a corn-bean-grain combination on the cash crop operations. The primary tillage practice used is the mouldboard plough; the secondary practice is the chisel plough used by only 3 operators in the test watershed.

Figure 4.7 Pittock Pilot Watershed



4.3 MEASUREMENTS AT THE PILOT WATERSHED APPLICABLE TO THIS STUDY

As part of the analysis, the MOE have set up water quality monitoring stations at each of the three pilot watersheds mentioned above. One such station is situated at the mouth of the watershed, from which the MOE and Beak Consulting are collecting water samples to be analyzed for suspended solids (i.e., sediment) and total and dissolved phosphorus. Another set of stations (three within each pilot watershed), have been organized to record surface run-off. Within each micro-basin, the amount of sediment and the flow rate from rainfall events will be accounted for.

As indicated, some more general analysis may be conducted at a larger watershed level. For example, if all cropland in a watershed, including the pilot watershed, achieved the reductions in erosion recorded in the SWEEP pilot watersheds, then the impacts on downstream activities may be much larger. Analyses conducted at a larger watershed level are dependent on data supplied by other SWEEP participants, particularly those involving aggregation and extrapolation of the SWEEP results.

Another issue is the assumed degree of participation in conservation technology, as one aggregates to larger watersheds. The 1986 OMAF survey on technology practices and the proposed 1990 MOE/OMAF survey should provide the needed information on the issue of participation.

It is our understanding, based on the terms of reference, that the macro-economic impact will not be addressed based on an assumption of 100 percent adoption of these conservation technologies across all of Ontario. Rather, the adoption rate will be based on relevant provincial surveys. That is, the MOE/OMAF survey data on adoption of technology packages will be used to aggregate beyond the PWD watersheds. The analysis will be conducted on a continuum that includes the pilot watersheds and larger (e.g., river) watersheds as end points. Provincial level data will be used, at times, as a reference point for comparisons and to demonstrate the degree of impact.

5.0 METHODOLOGY & ASSUMPTIONS

This chapter discusses the methodology used to calculate the impacts of in-stream sediment and phosphorus yields on stakeholders. Where possible, estimates of sediment and phosphorus damage to the specific activities were obtained from experts. As discussed earlier, spring sediment yields are normally measured in t ha^{-1}. The status quo, or current situation, of sediment and phosphorus yields are represented as 100 units at the stream. Expressing reductions in sediment yield as percentages, the question posed is if farm level soil erosion is reduced by x% (e.g., 10% and 40%), how are contaminant loads affected, and what will be the reduction in impact on downstream activities? Given the total dollar damage due to contaminant loads (as a result of cropland erosion) to the activities, a cost reduction was calculated. The cost per hectare was also calculated based on the area in which a particular downstream activity was expected to occur within.

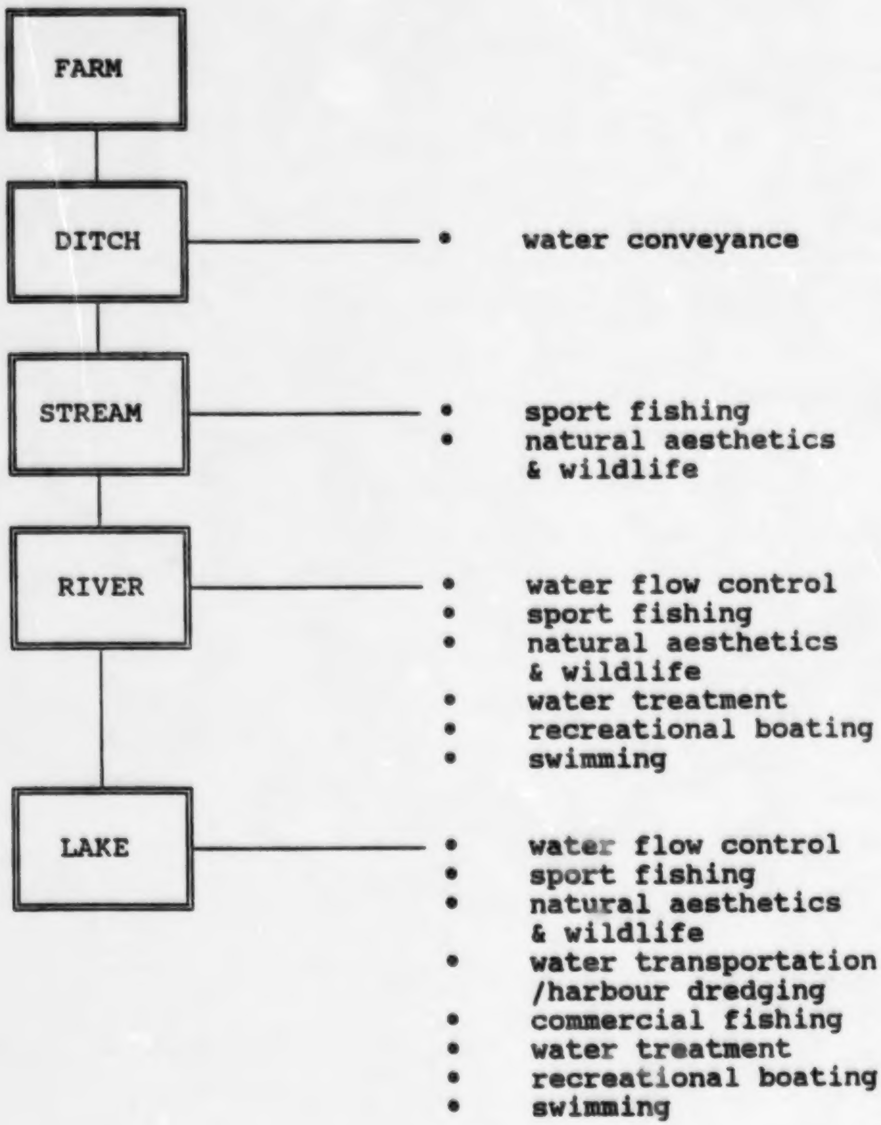
To trace sediment and phosphorus yields in-stream, certain assumptions were made at each consecutive water location and are described in the following paragraph. Below is a flow chart representing the expected path of sediment and phosphorus from the micro level (farm/field) to the individual downstream activities (Figure 5.1).

As can be seen from Figure 5.1, most of the activities are affected by sediment and phosphorus at the lake level. Three of the mentioned activities can also be affected at the river level, and as such, the impacts associated with reduced soil erosion will also appear on two levels. The resultant benefits for these particular activities, may therefore be relatively higher per hectare than the other downstream activities.

Two scenarios (discussed in the methodology) were used to capture estimates of high and low rates of sediment and phosphorus transportation within the stream, river and lake environments. Since the rate of transport of sediment after it enters the stream is affected by several factors (stream flow velocity,

sediment particles size and type etc.) it was necessary to utilize two scenarios to describe the changes in delivery from the stream to the lake.

Figure 5.1 Flow of Sediment and Phosphorus from the Farm to the Activity Locations



5.1 ASSUMPTIONS

The following assumptions have been because of the many unknown factors in this analysis.

5.1.1 Sediment Yields

Most researchers familiar with the soils and vicinity of the watersheds utilized in studies would agree that not all sediment delivered to streams and rivers from each watershed will make its way to a lake environment. Sediment containing very fine soils will have the largest effect on lake environments since it is easily suspended and transported. On the other hand, heavier sediment particles may dissipate to the stream bedload until stream velocity increases due to storm events. However, general assumptions about the transport of total sediment yields from the stream to the lake have to be made. In Scenario A, it is assumed that approximately 90 percent of the sediment and sediment bound phosphorus that enters the stream will end up travelling to each successive level of waterway. In Scenario B, 60 percent of the sediment that enters the stream travels to each successive level in the system.

Scenario A depicts a situation with a low percentage of settling occurring. Therefore, 10 percent of sediment and sediment bound phosphorus will be lost at each stage along the watershed. Scenario B represents another situation, where more settling in the stream bed occurs. This situation may appear where the stream connection is close to the lake.

5.1.2 Phosphorus Loading Impact

With respect to phosphorus, the amount reaching the lake environment will also react differently depending on settling rates and the amount of phosphorus attached to the soil particles. Huber (1982) estimates that the percentage of dissolved (soluble) phosphorus to total phosphorus is typically 1/3 to 1/2.

Gregor and Johnson (1980) also estimates that about 40 percent of total phosphorus is normally in the dissolved form. Consequently, we will assume that 60% of total phosphorus yields are absorbed by sediment, the remaining 40% of phosphorus is soluble and thus readily available for adsorption by plants and animals.

5.1.3 Pesticides

Pesticides can have a downstream impact, however the relationships between pesticide loadings and conservation practices are not well understood, nor are the relationships between current pesticide levels in water streams and downstream impacts. For this reason, the impact of pesticides is not addressed at this time.

5.2 METHODOLOGY

In Scenario A, it was assumed that 90% of the total annual sediment yield in the stream will reach the river and 90% of sediment deposited in the river or 81% of the sediment deposited in the stream will be transported to the lake.

In order to explain the flow of sediment and phosphorus delivery within the waterways, expected yields (i.e. 1.0 t ha^{-1} for sediment and 2.5 kg per hectare for phosphorus) will be expressed as units. Therefore, if in-stream sediment yields in stream are 1.0 t ha^{-1}, we have expressed this base value as 100 units of suspended sediment. Any reduction in stream sediment yields due to reductions in soil erosion will result in a reduction in the base value. For example, a 10% reduction in sediment delivery to the stream will result in a 10% reduction in sediment resulting in 90 units.

The following figures (5.2 to 5.5) identify and explain the flow of sediment and phosphorus at all levels along the watershed for a current situation, 10 percent, and 40 percent reduction in sediment delivery (choice of reductions are based

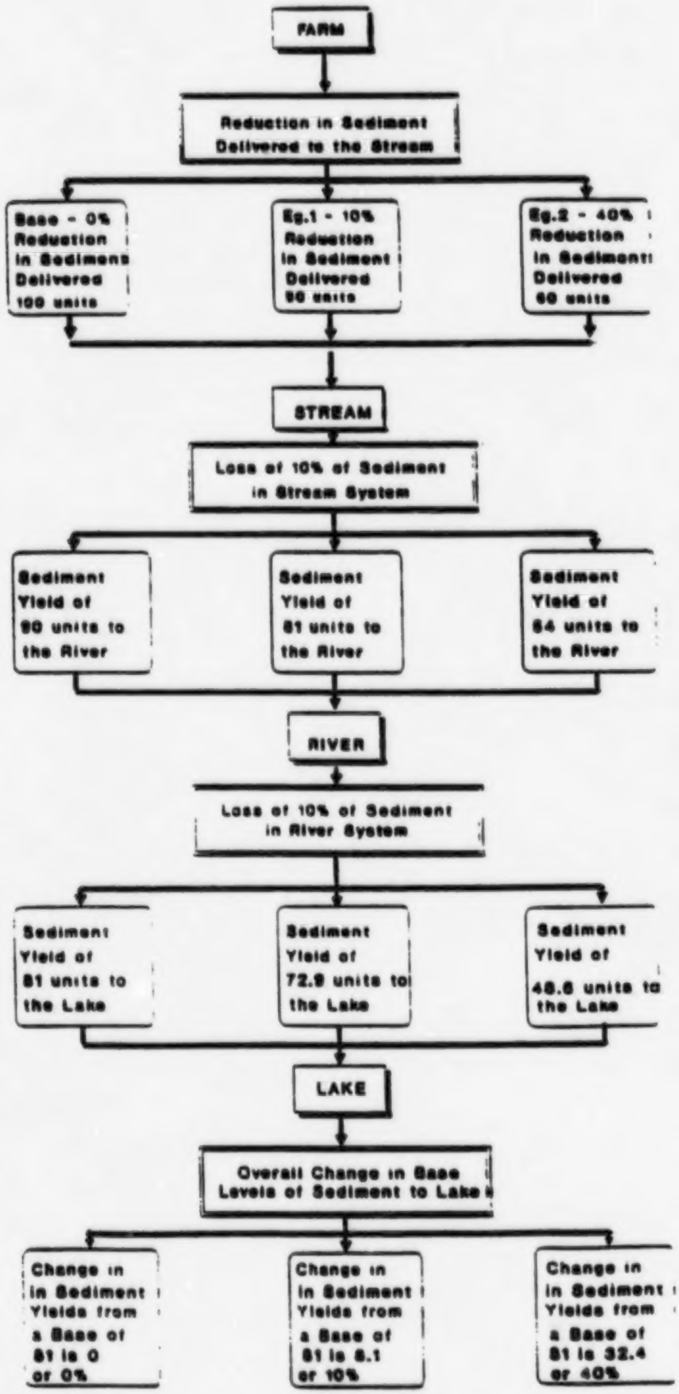
on expert consensus). Each diagram goes through the process of sediment and phosphorus delivery from the stream with 100 base units of sediment and phosphorus; to the river and finally to the lake.

5.2.1 Sediment Delivery

Figure 5.2 deals specifically with sediment delivery based on a loss of 10 percent (Scenario A) in sediment along each major water course. By examining Figure 5.2, we can see that the first step is a reduction in sediment delivery of either 0%, 10% or 40%. These reductions will cause changes to the base sediment yield of 100 units equal to 100 units (base example), 90 units (example 1) and 60 units (example 2) of sediment depending on the reduction in sediment delivery.

Once sediment enters and flows through a stream environment, a portion (10%) of the sediment may be deposited as bed load or absorbed by aquatic plants and animals. Therefore, by the time the sediment reaches the river, we assume 10% of the sediment is lost. We now derive new sediment yields of 90 units (base), 81 units (example 1) and 54 units (example 2). At the river, a further 10% of sediment is lost for the reasons explained above, resulting in a new set of sediment delivery yields of 81 base units, 72.9 units for example 1 and 48.6 units for example 2. These values represent the levels of sediment that will reach the lake environment. As Figure 5.2 illustrates, the resulting change in sediment levels are determined by subtracting the changes experienced in example 1 and 2 from the base case (if no reduction were to occur) in sediment levels.

Figure 5.2 Sediment Delivery Flow Diagram - Scenario A



The second scenario, Scenario B, involves an illustration of a slow moving water system (Figure 5.3). In slower moving streams a higher proportion of sediment will be deposited as bed load. Similarly, in slow moving rivers or rivers where the stream connection is far from the lake, more sediment will deposited upstream allowing for less deposit downstream. In this scenario (B), it was assumed that only 60% of the sediment deposited in the stream will be transported to the river and 60% of sediment transported to the river will be transported to the lake.

Accounting for the amount of sediment that gets trapped at each watershed level and the resulting numbers obtained, the above explanation also holds true for Scenario A.

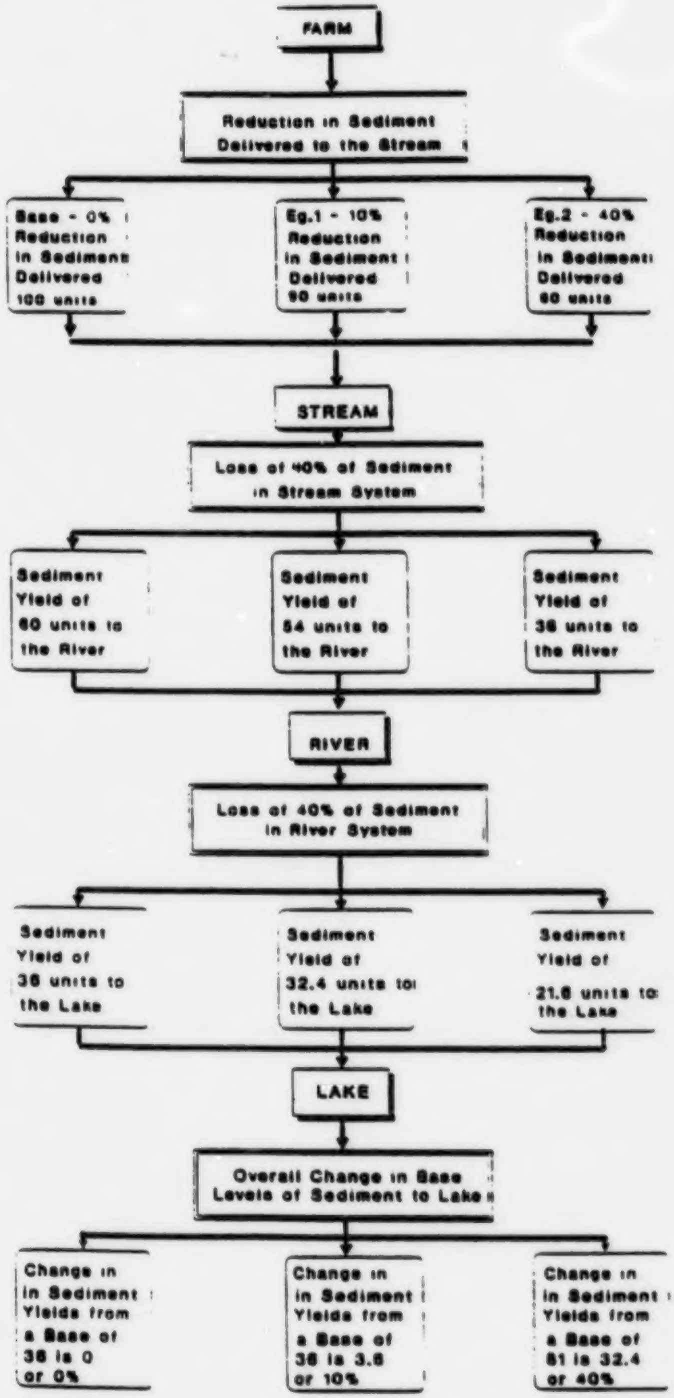
Subsequent analysis reveals that sediment yields at the lake will be 36 units with no reduction in sediment delivery, 32.4 units with a 10% reduction in sediment delivery to the stream and 21.6 units for a 40% decline in sediment at the stream.

5.2.2 Phosphorus Delivery

Phosphorus behaves differently than sediment once it enters a watercourse. Not all 100 units of phosphorus that enter the stream will travel to the final destination, the lake. A portion of the soluble phosphorus (consisting of 40% of total phosphorus) is utilized for plant growth once it enters the waterway. A portion of the absorbed phosphorus is also lost for a short time to a stream's physical components.

The impact of conservation on phosphorus loadings is different than on sedimentation. As was indicated earlier, phosphorus is broken down into two parts, phosphorus in the water and phosphorus in sediment. Assuming 100 units of phosphorus at the stream represents total loading, 40 units of phosphorus reach the stream in the water soluble form and the remaining 60 units is found bound to sediment.

Figure 5.3 Sediment Delivery Flow Diagram - Scenario B



Assuming that the 40 units of soluble phosphorus is being utilized for plant growth etc., the remaining 60 units of phosphorus is tied to sediment. Utilizing the same logic as was incorporated in the previous section for sediment delivery we can assess how a reduction in sediment delivery will affect total phosphorus yields. Therefore, in Scenario A (Figure 5.4), a 10% reduction in sediment delivery will only affect the portion of the phosphorus tied to sediment (60 units). The remaining 40 units will be not be affected by decreases in sediment delivery. Reducing 60 units by 10% plus the additional 40 units, yields a total phosphorus load of 94 units. Similarly, for a 40% reduction in sediment delivery, we would find an overall phosphorus yield of 76 units (60 units * 40% decrease = 36 units + 40 units).

Utilizing the same logic for Scenario B (Figure 5.5), with a loss of 40 percent of the phosphorus to each successive water system, we again begin with the 100 units, 94 units and 76 units associated with a 0%, 10% and 40% decrease in sediment delivery. Once the phosphorus enters the river, 40% of the total yield will have been deposited as bed load with the sediment or utilized by plants for growth. This leaves 60 units, 56.4 units and 45.6 units of phosphorus at the river. At the lake environment, the base case now becomes 36 units, example 1 (10% reduction) becomes 33.8 units and example 2 (40% reduction) 27.4 units. These values correspond to change in phosphorus yields from the base case of 6% and 24%.

Some damages, such as harbour dredging will be omitted in later analysis since they may not pertain to the river basins being examined. If, for example, the Pittock watershed does not eventually drain into an operating harbour then no costs or benefits associated with reduced soil erosion apply to the activity of harbour dredging for that particular case. For other case studies, there may be evidence of damage but no research has been done to quantify the cost impacts.

Figure 5.4 Phosphorus Delivery Flow Diagram - Scenario A

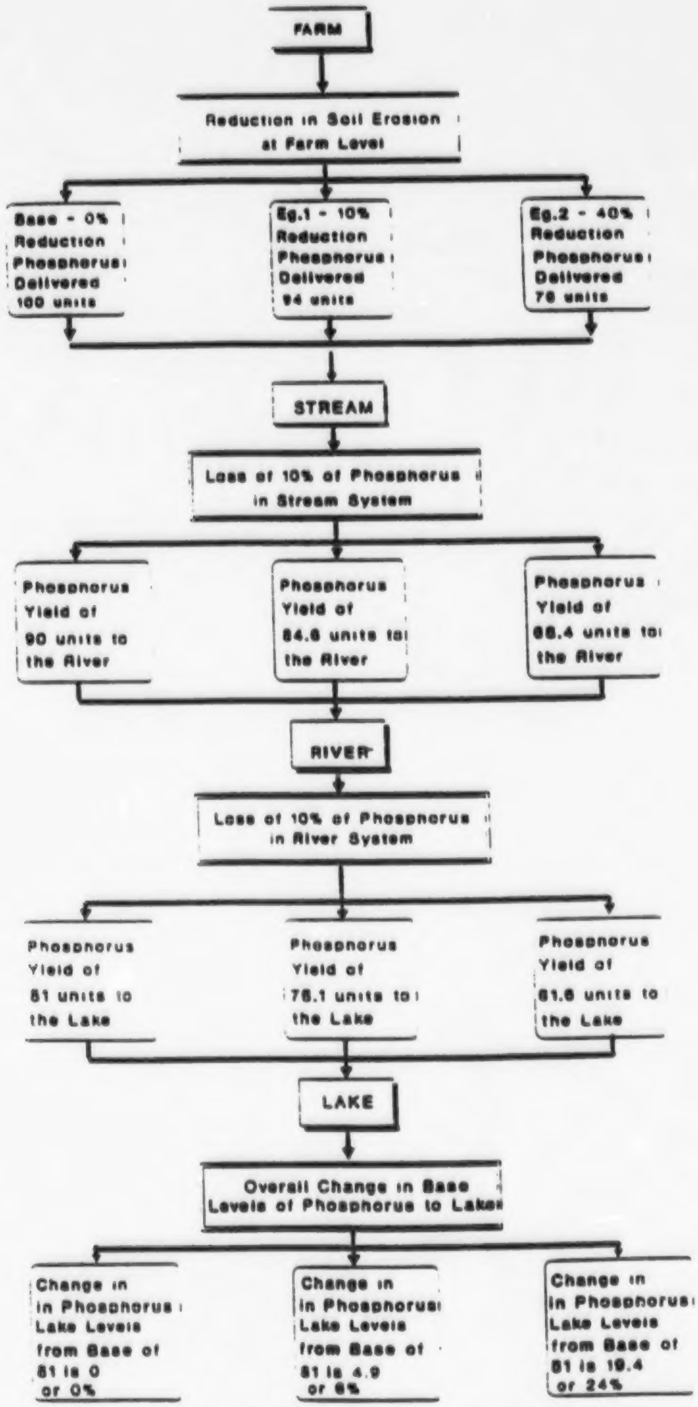
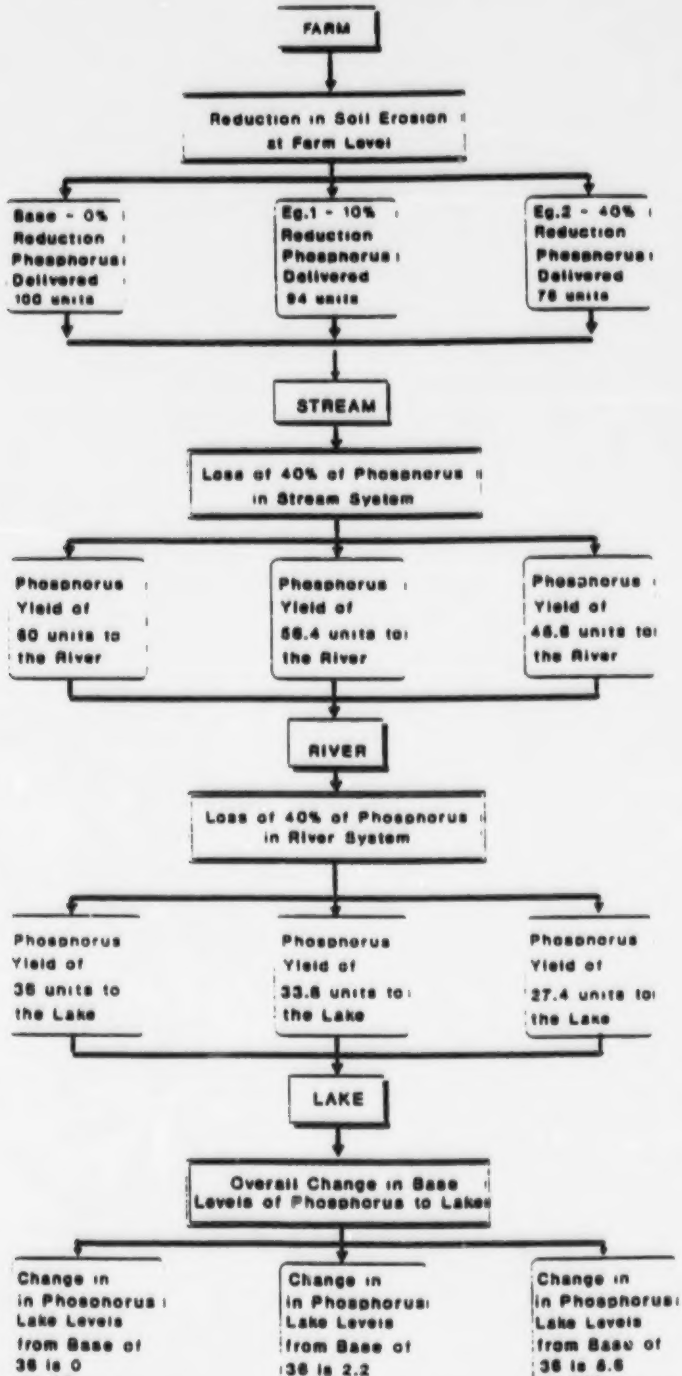


Figure 5.5 Phosphorus Delivery Flow Diagram - Scenario B



6.0 PRICED MARKET ACTIVITIES

Priced downstream market activities, include activities such as water transportation and commercial fishing. They have clearly quantified and measurable values. Impacts on any of the priced market activities will have a direct impact on the economy. For example, measuring the impact of sediment on fish populations will reveal how the fish market may deteriorate from harmful sediment loading.

6.1 WATER TRANSPORTATION/HARBOUR DREDGING

Sediment build-up is a persistent problem that both small recreational and larger commercial harbours must contend with. The problem can not be ignored because it will interfere with the normal operations of a water transportation facility. Dredging is the usual procedure used to eliminate excess sediment and sludge from harbours and transportation cores.

Dredged material is roughly composed of two source materials: 1) sediment transported by rivers from upstream erosion; and 2) sediment deposited by wave actions along lake shorelines.

Dickson and Wall (1981) estimate that $700,000 is spent annually to dredge sediment from small craft harbours. It is also estimated that an additional $7.5 million is spent annually to dredge sediment from commercial harbours in Ontario (Dickson and Wall, 1981). Therefore, it is estimated that a total $8.2 million is spent annually in Ontario to keep harbours free from sludge and sediment build-up. Adoption of conservation tillage practices will assist in reducing sediment accumulation and thus decrease the need for or the cost of future dredging projects.

The identification of sources of sediment and contaminants in the watershed is addressed by the International Reference Group on Great Lakes Pollution from Land Use Activities.

Table 6.1 below, summarizes the total dredging volumes in the Great Lakes associated with the maintenance of Canadian harbours and waterways for commercial navigation (water transport). American dredging volumes are somewhat larger than Canadian dredging volumes. Total Canadian volumes for the five year period between 1974 and 1979 are only 12% of that of the United States dredging volumes (or 8 times less). Lake Erie clearly dominates dredging in the Great Lakes accounting for 62% of the total volumes; Lake Michigan accounts for 15%, Lake Ontario 9% and Lake Superior and Lake Huron 7% each (IJC, 1982).

Table 6.1 Canadian Great Lakes Dredging Volumes, 1980 - 1984

Year	Volume (m^3)
1980	613 760
1981	504 655
1982	292 425
1983	746 416
1984	429 743
Total	2 587 000
Annual Average	517 400

Source: International Joint Commission, 1982.

Table 6.2 reveals that a large portion (72%) of the Canadian volumes occurs in Ontario with Thunder Bay contributing the largest amount of dredging volumes. Joe Grossi (Senior Marine Engineer) from the Federal Department of Public Works, indicated that a 1984 dredging project for Lake Superior

accounted for 161,000 m^3 of dredged material at a cost of $556,995. According to the Register of Great Lakes Dredging Projects, 1980 - 1984 the cost of Ontario projects (excluding confinement costs) were $4.60 m^3. Draft figures for the 1985 - 1989 period suggest that dredging costs are approximately $9 m^3 for open disposal and $15 to $22 m^3 for confined material. Based on the annual average dredging volumes shown in Table 6.2 the average cost per m^3 would be $15.85.

Table 6.2 Locations of the Largest Total Dredging Volumes in Ontario, 1975 - 1979

Location	Volume (m^3)
Thunder Bay	580 000
Southeast Bend Cut-off	330 000
Hamilton	270 000
Port Stanley Harbour	230 000
Goderich	200 000
Whitby	190 000
Total	1 800 000

Source: International Joint Commission, 1982.

Traditionally, disposal of dredged material has taken place utilizing the most convenient method, in designated open water dumping locations, namely lakes. Since the 1970's environmental assessments have been used to indicate if the disposal of dredged material would have any adverse affects on the biota through contamination. As a result, most of the material dredged today requires confinement in storage tanks. IJC (1990) indicate that 71 percent of dredged material was confined during 1980 and 1984. In a 1983 report by Birch *et al.*, estimates of the proportion of dredged material requiring confined disposal to unconfined disposal was 85 percent to 15 percent respectively. The reason for confinement is due to the heavily polluted materials (e.g., phosphorus, metals and harmful chemicals) found in the sediment.

The IJC recognizes five distinct categories of dredged material disposal:

1) upland -	involves moving the material away from the shore and placing it in a pre-approved disposal site;
2) confined -	is a shore-based construction containing sediments too contaminated to be otherwise disposed of;
3) open -	is barge transported sediment to an approved offshore water site;
4) beach -	is the application of clean, sandy dredged material to an adjacent beach site; and
5) reuse -	is dredged material of acceptable quality used for the build up of the littoral zone, or the reinforcement of breakwalls and sandpits areas.

Most of the polluted material found in dredged material originates almost exclusively from rivers (assume 90%), although not necessarily from agricultural sources. In Birch *et al.*'s report, Wade and Heady suggest that the proportion of sediment from cropland sources in Michigan is 34% of overall dredged material. Dickson and Wall, 1988 utilize a comparable figure. They suggest that sediment from agricultural sources is responsible for 33% of total sediment loads in the Great Lakes (Dickson and Wall, 1988). We therefore will assume that 30% of dredged material from commercial and recreational harbours in Canada can be attributed to cropland erosion.

Depending on the amount of the dredged material that requires confinement (56% in Toronto Harbour or 85% of total dredging projects - Corps of Engineers) the cost of disposal will change. A series of case studies, referenced by Clark indicate that less-damaging disposal methods can still increase project costs by 65 percent to over 1,000 percent.

However, for this analysis we will assume that total annual dredging costs attributed to agriculturally transported sediment will be a portion of the total cost mentioned earlier ($8.2 million). Assuming that 30% of the dredged

material can be attributed to cropland erosion, then $2,460,000 is the total dredging costs due to agriculture.

The next step is to calculate the area contributing to the problems based on drainage area figures from Table 6.3 and the associated main areas of concern (i.e., Lake Erie contributes 62% of total dredging volumes). The main agricultural area assessed to be contributing to dredging problems is 1.68 million ha.

Figure 6.1 indicates the benefits to be achieved through a reduction in in-stream sediment yields. Scenario A and a 40% reduction in soil erosion is utilized as an example. Therefore, if dredging costs decrease at the same rate (proportionally) as sediment, phosphorus and contaminant loadings decrease, then the relationship between reduced sediment yield and costs would be 1:1. To calculate a reduction in costs associated with a reduction in sediment (and the associated contaminants), assuming sediment delivery is reduced by 40 percent the change in sediment yield at the lake would be 32.4 units or 40 percent (from Figure 5.2). The 40 percent reduction in costs is then multiplied by the total cost of dredging associated with agricultural soil erosion ($2,460,000). The resulting figure of $984,000 represents the total benefit to water transportation/harbours in Ontario for a 40% reduction in sediment yield (Scenario A). The total agricultural area associated with dredging activities is calculated to be 1.68 million hectares which correlates to a net benefit of 59 cents per hectare for a reduction in sediment yield.

6.2 COMMERCIAL FISHING

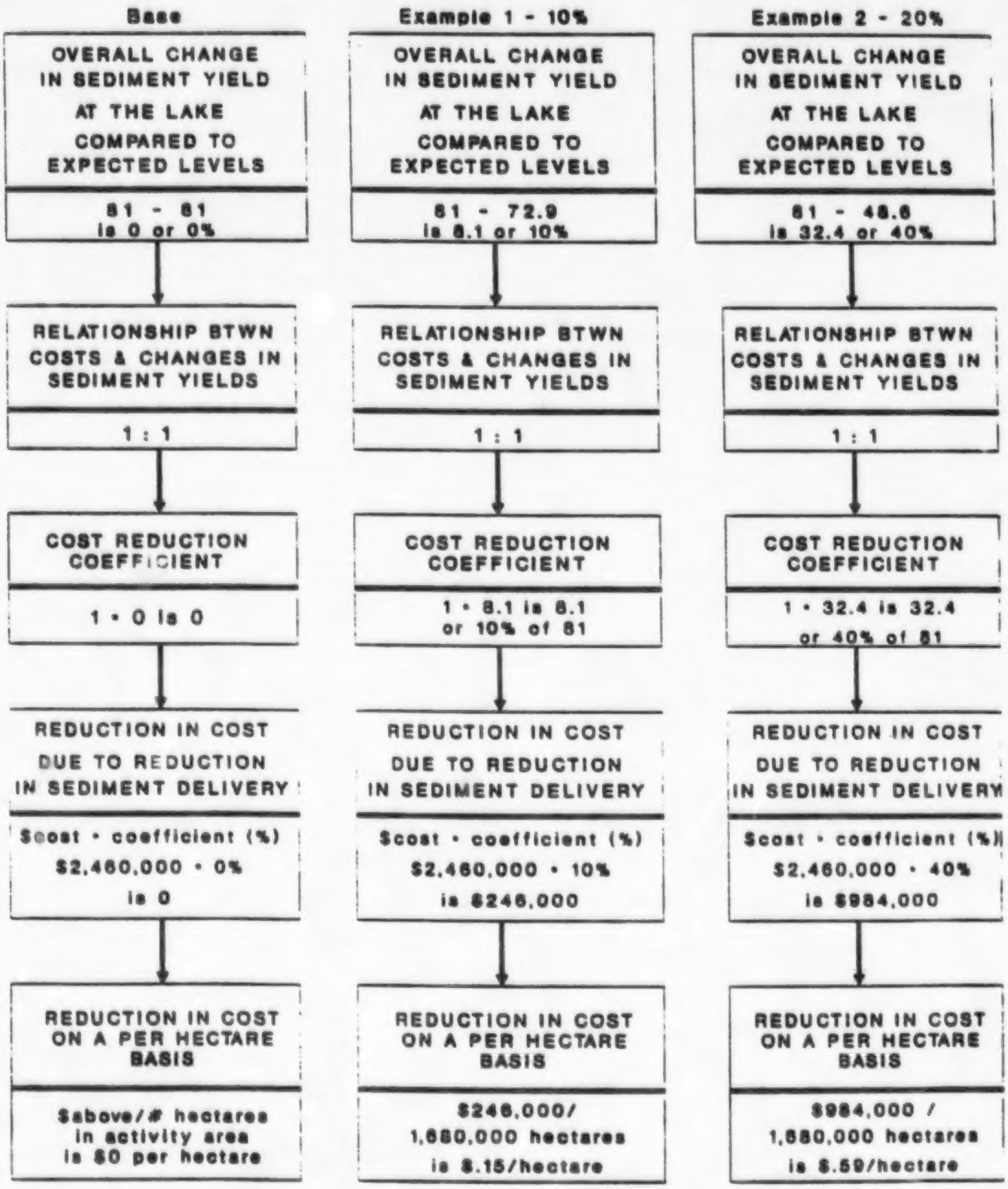
Sediment and associated contaminants can affect aquatic organisms at every link in the food chain, from microscopic algae to valuable game fish. They cause damage either directly, through physically or biologically affecting an organism itself, or indirectly, through destroying the organism's required habitat (Clark, 1987).

Table 6.3 Proportional Area (Hectares) of Ontario's Drainage Basins Flowing into the Great Lakes

Drainage Basins	Total Area	Southern Ontario	Western Ontario	Central Ontario	Eastern Ontario
1. Lake Huron & Georgian Bay					
. Ausable, Bayfield & Maitland	443,470	110,870	332,600		
. Saugeen	391,140		391,140		
. Nottawasaga to Owen Sound	407,550		407,550		
. Holland, Severn	549,910		357,440	420,390	
. Lakeside Land	488,750	224,440	464,310		
Total	2,280,820	335,310	1,953,040	420,390	0
2. Lake St. Clair					
. Thames	594,340	475,470	118,870		
. Sydenham	315,150	315,150			
. Lakeside Land	92,770	92,770			
Total	1,002,260	883,390	118,870	0	0
3. Lake Erie					
. Kettle to Haldimand	301,180	301,180			
. Grand	656,810	262,720	394,090		
. Lakeside Land	311,200	311,200			
Total	1,269,190	875,100	394,090	0	0
4. Lake Ontario					
. Oakville to Pickering	352,570	17,600	300,000	34,970	
. Welland, W. Lincoln	178,730	178,730			
. Trent	1,050,840	-		1,050,840	
. Moira to Gananoque	676,910			169,220	507,690
. Lakeside Land	865,640	216,410		649,230	
Total	3,124,690	412,740	300,000	1,904,260	507,690
5. Lake Michigan	2,000,000				
6. Lake Superior	2,171,000				
Total of Above	11,847,960	2,506,520	2,766,000	2,324,650	507,690
Remainder of Province	79,895,380				
Total Province	91,743,340				

Source: Ontario Ministry of Agriculture and Food. Economics Information, Report No. 89-08. Survey of Pesticide Use in Ontario, 1989.

Figure 6.1 Effect of Reductions in Sediment on Water Transportation - Scenario A



Some of these effects are caused by high levels of turbidity resulting from suspended sediment and algae. Increasing levels of turbidity have several effects on fish populations including unfavourable water temperature conditions. Several researchers have shown that fry emergent rates have an inverse relationship with the percentage of fine sediment in the stream (Loomis, 1989). This has been observed in water bodies with low or nonexistent fish populations and associated high turbidity levels.

Sediment-related factors also negatively affect fish populations by affecting embryo survival rates, the rate of fry emergence from gravel, and the amount of rearing space. Sediment can harm fish by damaging feeding areas and by reducing fish respiratory efficiency. Sediment reduces the inflow of oxygen to the embryos and traps the embryo's output of toxic metabolic wastes, thus, negatively affecting embryo survival rates (Loomis, 1989).

Suspended sediment also becomes a problem for fish that depend on visual cues for courtship and spawning behaviour. Some fish may be affected if they are unable to carry out their complex courtship behaviour that seems to be required for their successful reproduction. The spawning of large-mouth bass, for instance, has been delayed in muddy ponds for as much as 30 days after which spawning took place in nearby clear ponds (Clark, 1987).

Even if fish eggs are successfully laid, turbidity and its effects on sunlight and oxygen availability may interfere with normal hatching practices to reduce larvae size at hatching. This makes it more difficult for larvae to visually detect their food source; plankton.

High levels of suspended solids have also exposed fish to gill damage, abrasion and fish rot (Clark, 1987). Sedimentation can have a dramatic affect on fish and the aquatic environment by destroying the habitat of bottom dwelling organisms. One study estimates that sedimentation has destroyed one-half of the fish (including the sea lamprey) and oyster spawning grounds in the upper estuary of the Chesapeake Bay (Ritchie, 1968).

Fish also exhibit reproductive and population problems due to excessive pesticide loadings. Further research may suggest to what extent pesticides are causing limitations to the commercial fishing industry. Until this evidence can be found, pesticides although important will not be included in the analysis of the commercial fishing industry in Ontario.

However, specific information about excessive phosphorus loading is available. It is known that decomposition of algae will destroy fish populations by combining with biochemical oxygen depletion (BOD) loadings to reduce oxygen levels. In Lake Erie, for instance, eutrophication-caused oxygen depletion has been held responsible for making much of the area uninhabitable for many fish and their food species, while other fish (perch) do quite well in increased phosphorus conditions (Clark, 1987). Along with overfishing and siltation, eutrophication was the cause for the extinction of the lake trout in Lake Erie during the seventies (Welch, 1978).

Increased nutrient loadings in a water body change its species composition and dramatically increase the quantity of microscopic plants it contains. Therefore, we may see a shift in fish species from more valuable fish in terms of the price per pound received in the market; or a decrease in the number of commercial fisheries employed and as a result decrease in the number of processing and wholesale manufacturing plants. The commercially demanded species of fish seem to be the least tolerant and most sensitive to both sedimentation and eutrophication. Therefore, lower value species may begin to replace high-value (less hardy) fish as the problems associated with soil erosion persist.

In this regard, a value for the replacement of trout and whitefish (which have experienced decreases in populations due to increased phosphorus loading and dissolved oxygen) with lower value fish such as smelt will be calculated. This value will be used to express the cost/ benefit of reduced sediment and phosphorus yields to Ontario commercial harvests.

6.2.1 Commercial Fish Landings in Ontario and the Resulting Effects of Soil Erosion

In 1987, Canadian commercial fish landings were approximately 1.51 million tonnes worth $1.57 billion, compared to 1.53 million tonnes (m.t.) of fish landed in 1986 and valued at $1.35 billion (Canada, Department of Fisheries and Oceans, 1989). Comparative figures for Ontario show that in 1987 cumulative landings of commercial fish were 27,800 m.t. (61,272,954 lbs.) worth $48.4 million, almost exclusively from Lake Ontario and Lake Erie (See Table 6.4).

The impact of erosion on commercial fishing is reported in Table 6.5. Based on Ontario cumulative landings for 1987 and sediment factors utilized by the Erosion Control Committee, the potential percentage increase in sediment-sensitive fish landings and the resultant increase in value expected from the elimination of excessive sediment from Ontario waterways is determined. The sediment factor indicates the impact of current erosion on fish populations. Thus a .75 sediment factor implies that fish populations would be 75 percent larger without erosion. Multiplying the sediment factor by the number of fish being caught will determine the potential increase in the number of fish caught with the elimination of excess erosion. The estimates in Table 6.5 also reveal the total potential increase in fishing value due to the elimination of sedimentation from cropland, which is calculated to be $25,900,000.

If we assume that costs to the commercial fishing industry attributable to soil erosion will decrease at the same rate that sediment and phosphorus loadings decrease, then the coefficient between reduced sediment/phosphorus delivery and costs would be 1:1. According to Scenario A, the benefit associated with a 40 percent and reduction in sediment, or 32.4 units, is $10.4 million or $2.36 per hectare.

Table 6.4 Ontario Commercial Fish Harvest, 1987 (In Pounds and Dollar Values)

Species	Total Harvest (Pounds)	Total Value ($)
Bowfin	20,302	4,689
Yellow Perch	11,626,305	19,140,494
Yellow Pickerel	7,643,499	13,244,646
Lake Whitefish	5,230,117	5,007,954
Smelt	25,563,967	4,156,748
White Bass	2,977,166	2,491,559
Chub	991,007	1,165,449
White Perch	1,218,916	564,423
Lake Trout	496,117	522,841
Lake Herring	1,850,377	465,920
Eel	229,018	246,923
Sucker	1,270,625	213,275
Northern Pike	312,592	212,811
Bullhead	509,192	204,452
Sturgeon	43,925	153,120
Sauger	68,726	115,964
Catfish	141,530	72,399
Carp	157,574	61,921
Mixed Scrap	159,940	61,630
Crappie	42,940	55,411
Freshwater Drum	353,845	45,699
Burbot (Ling)	121,205	34,213
Sunfish	123,285	30,153
Caviar	5,603	22,712
Pink Salmon	26,958	18,901
Mixed Scrap	159,940	61,630
Round Whitefish	41,709	12,883
Rock Bass	35,954	10,796
Goldeye	3,947	1,466
Shad	6,614	286
Total Harvest (lbs)	61,272,954	
Total Value ($)		$ 48,339,738

Lake Erie has 96.6% of the fish market
Lake Ontario has 3.4% of the fish market
Source: L.A. Spencer, OMAF, Ontario Commercial Fish Harvest - 1984, (Jan. 1989).

Table 6.5 Total Annual Cost of Cropland Sedimentation to Commercial Fishing in Ontario

	1	2	3 (1)*(3)	4 (2)/(1)	5 (5)*(4)	6
Species	Quantity of Fish Caught In Ontario By Species 1987 (m.t.)	Value of Fish Caught in 1987 ($'000,000)	Sediment Factor[1]	Potential Increase in Number of Fish Caught (m.t.)	Fishing Value at Previous Catch Rates ($/m.t.)	Increase in Value ($000,000)
Yellow Pickerel	3,467	13.2	0.75	2,600	3,807	9,900,000
Whitefish	2,390	5.0	0.50	1,195	2,902	3,468,000
Perch	5,827	19.7	0.50	2,914	3,380	9,850,000
Smelt	11,600	4.2	0.25	2,900	362	1,050,000
Lake Trout	225	0.5	1.00	225	2,222	500,000
Other	4,291	5.8	0.20	858	1,352	1,160,000
TOTAL	27,800	48.4		10,692		25,900,000

1. Sediment Factors - show the potential % increase in fish populations that may result from the elimination of excess sediment from waterways. The values are based on values used by Dickson and Wall, 1988.

Figure 6.2 shows that the following cost reductions in commercial fishing will result from reductions in soil erosion. A 10% reduction in sediment under Scenario A, will achieve a savings of $0.59 per hectare. A 40% reduction in sediment delivery will quadruple ($2.36) the savings realized for the commercial fishing industry.

Table 6.6 shows how a change in fish harvested due to damage from phosphorus may affect the commercial fishing industry. For example, lake trout and whitefish are two species known to be affected by oxygen depleted lakes due to agriculture. As their populations diminish they could be replaced by unaffected fish such as smelt. This in effect will reduce the value of lake trout and whitefish due to decreased catch rates, on one hand, and increase the harvest value of smelt on the other. The overall effect on the total value of fish caught would be a decrease from $48.4 million to $46.1 million, or a $2.3 million loss.

Depending on the extent to which higher value fish are replaced by lower value fish, $2.3 million could represent a likely impact scenario for the effect of excessive phosphorus loads on the commercial fishing industry in Ontario.

Figure 6.3 indicates that given a reduction in phosphorus of 40 percent a $2.3 million loss in commercial harvest value should generate a cost of 24 percent, or $552,000 (or $2.49 per hectare).

Figure 6.2 Effect of Reductions in Sediment on the Commercial Fishing Industry - Scenario A

Base	Example 1 - 10%	Example 2 - 40%
OVERALL CHANGE IN LEVEL OF SEDIMENT AT THE LAKE COMPARED TO EXPECTED LEVELS	OVERALL CHANGE IN LEVEL OF SEDIMENT AT THE LAKE COMPARED TO EXPECTED LEVELS	OVERALL CHANGE IN LEVEL OF SEDIMENT AT THE LAKE COMPARED TO EXPECTED LEVELS
81 - 81 is 0 or 0%	81 - 72.9 is 8.1 or 10%	81 - 48.6 is 32.4 or 40%
↓	↓	↓
RELATIONSHIP BTWN COSTS & CHANGES IN SEDIMENT LEVELS	RELATIONSHIP BTWN COSTS & CHANGES IN SEDIMENT LEVELS	RELATIONSHIP BTWN COSTS & CHANGES IN SEDIMENT LEVELS
1 : 1	1 : 1	1 : 1
↓	↓	↓
COST REDUCTION COEFFICIENT	COST REDUCTION COEFFICIENT	COST REDUCTION COEFFICIENT
1 • 0 is 0	1 • 8.1 is 8.1 or 10% of 81	1 • 32.4 is 32.4 or 40% of 81
↓	↓	↓
REDUCTION IN COST DUE TO REDUCTION IN SEDIMENT YIELDS	REDUCTION IN COST DUE TO REDUCTION IN SEDIMENT YIELDS	REDUCTION IN COST DUE TO REDUCTION IN SEDIMENT YIELDS
$cost • coefficient (%) $25,900,000 • 0% is 0	$cost • coefficient (%) $25,900,000 • 10% is $2,590,000	$cost • coefficient (%) $25,900,000 • 40% is $10,360,000
↓	↓	↓
REDUCTION IN COST ON A PER HECTARE BASIS	REDUCTION IN COST ON A PER HECTARE BASIS	REDUCTION IN COST ON A PER HECTARE BASIS
$above/# hectares in activity area is $0 per hectare	$2,590,000 / 4,393,880 hectares is $.59/hectare	$10,360,000 / 4,393,880 hectares is $2.36/hectare

Table 6.6 Total Annual Cost of Phosphorus to Selected Commercial Fish in Ontario

Species	Scenario A: Harvest without Change		Scenario B: 50% Harvest Decrease for Species Sensitive to Phosphorus; 50% Harvest Increase for Smelt	
	Quantity of Fish Caught In Ontario By Species 1987 (m.t.)	Value of Fish Caught in 1987 ($'000,000)	Quantity of Fish Caught In Ontario By Species 1987 (m.t.)	Value of Fish Caught in 1987 ($'000,000)
Yellow Pickerel	3,467	13.2	3,467	13.2
Whitefish	2,390	5.0	1,195	2.5
Perch	5,827	19.7	5,827	19.7
Smelt	11,600	4.2	12,908	4.7
Lake Trout	225	0.5	113	0.2
Other	4,291	5.8	4,291	5.8
TOTAL	27,800	48.4	27,800	46.1

Figure 6.3 Effect of Reductions in Phosphorus on the Commercial Fishing Industry - Scenario A

Base	Example 1 - 10%	Example 2 - 40%
OVERALL CHANGE IN LEVEL OF PHOSPHORUS AT THE LAKE COMPARED TO EXPECTED LEVELS	OVERALL CHANGE IN LEVEL OF PHOSPHORUS AT THE LAKE COMPARED TO EXPECTED LEVELS	OVERALL CHANGE IN LEVEL OF PHOSPHORUS AT THE LAKE COMPARED TO EXPECTED LEVELS
81 - 81 is 0	81 - 76.1 4.9 or 6%	81 - 61.6 is 19.4 or 24%
RELATIONSHIP BTWN COSTS & CHANGES IN PHOSPHORUS LEVELS	RELATIONSHIP BTWN COSTS & CHANGES IN PHOSPHORUS LEVELS	RELATIONSHIP BTWN COSTS & CHANGES IN PHOSPHORUS LEVELS
1 : 1	1 : 1	1 : 1
COST REDUCTION COEFFICIENT	COST REDUCTION COEFFICIENT	COST REDUCTION COEFFICIENT
1 • 0 is 0	1 • 4.9 is 4.9 or 6% of 81	1 • 19.4 is 19.4 or 24% of 81
REDUCTION IN COST DUE TO REDUCTION IN PHOSPHORUS	REDUCTION IN COST DUE TO REDUCTION IN PHOSPHORUS	REDUCTION IN COST DUE TO REDUCTION IN PHOSPHORUS
$cost • coefficient (%) $2,300,000 • 0% is 0	$cost • coefficient (%) $2,300,000 • 4.9 is $138,000	$cost • coefficient (%) $2,300,000 • 24% is $552,000
REDUCTION IN COST ON A PER HECTARE BASIS	REDUCTION IN COST ON A PER HECTARE BASIS	REDUCTION IN COST ON A PER HECTARE BASIS
$above/# hectares in activity area is $0 per hectare	$138,000 / 4,393,880 hectares is $.091/hectare	$552,000 / 4,393,880 hectares is $.13/hectare

7.0 GOVERNMENT SERVICES

Many of the downstream activities affected by soil erosion are services provided by local and provincial government offices. Therefore, government run facilities will benefit greatly by any decreases in soil erosion and pollutant loadings to the river and lake systems of Ontario. Consequently, it would be very beneficial if the negative impacts created by soil erosion and excessive run-off could be controlled, thereby curtailing the need for increasing government expenditures.

7.1 WATER CONVEYANCE

Two groups are responsible for the removal of sediment that accumulates within drainage systems. The Ministry of Transportation and Communication is responsible for roadside ditches while the Ontario Ministry of Agriculture and Food is responsible for municipal drains.

Sediment build-up in ditches and municipal drains reduces the efficiency of drainage systems which then must periodically be cleaned out. Of the total sediment that eventually settles as a result of agricultural erosion, only a portion is due to gross on-farm sediment movement. Sediment run-off depends on many different factors (slope, soil type and texture etc,).

According to Dickson and Fox (1988), annual spending on sediment removal from municipal drains is $11.2 million (in 1987 dollars). An additional $4.2 million is spent by the Ministry of Transportation and Communication for roadside sediment removal (Erosion and Sedimentation Control Committee, 1983). According to expert opinion, the majority of sediment found in drains originates from drainage banks. Therefore, drainage construction is a very important factor determining the amount of sediment entering the stream and the life of the drain.

Consequently, the amount of sediment entering Ontario's rivers and lakes from fields is small relative to other sources. Assuming that this proportion is 25%, then $3.9 million can be the cost attributable to sediment removal of drains due to cropland erosion. Total expenditures for removal on individual watersheds will change depending primarily on soil types (finer soils will exhibit higher delivery rates). In order to determine any particular watershed's share of total expenditures for sediment removal, the total expenditures ($15.4 million) must be divided by the total improved cropland area in Ontario which is 4,518,713 hectares (Ontario Ministry of Agriculture and Food, 1987). This indicates that the total annual water-conveyance maintenance cost is $3.41 per hectare of improved cropland.

However, these estimates tend to be conservative. It has been observed that high turbidity levels create additional costs to pump water through the drains. Secondly, drains are frequently left for years without the regular dredging or sediment removal. As more sediment builds up within a ditch there is a greater probability of a flood occurring due to the reduced carrying capacity of the conveyance system. Suspended sediment can also clog pumping systems resulting in increased equipment maintenance costs. When repairs to the conveyance system are required, drains are temporarily placed out of order creating an additional (indirect) cost to sediment removal. Therefore, by allowing sediment to build up in drains for long periods the cost of maintenance can be much higher than expected.

Generally, agricultural soil erosion makes up roughly 20% of the material removed from drainage ditches. According to expert opinion, the relationship between the cost of clean-up and changes in sediment yield is not linear. As sediment decreases, the benefits will increase substantially more. Therefore, it is assumed that a 1:1.5 relationship between sediment yield and the cost of clean up exists. This means that as we decrease sediment yields the cost to clean the drain will decrease by one and a half times.

Consequently, if sediment yield within a drain is reduced by 40%, there will be a much greater reduction in maintenance costs. As discussed earlier, the

associated cost of removing agricultural sediment from drains is $3.9 million. A 40 percent reduction in sediment reduces costs by $2.3 million, assuming a one-to-one and a half relationship. Figure 7.1 helps to explain this.

According to a Ministry of Transportation advisor, the maintenance costs expressed above encompass drains throughout Ontario, excluding Northern Ontario and a small part of Eastern Ontario. Therefore, from Table 6.3, the area regulated for maintenance checks by the Ministry of Transportation encompasses 5,918,600 hectares. We can therefore conclude that the benefits to be gained by reducing soil erosion by 40%, according to Figure 7.1 are 40 cents per hectare, or $2.34 million.

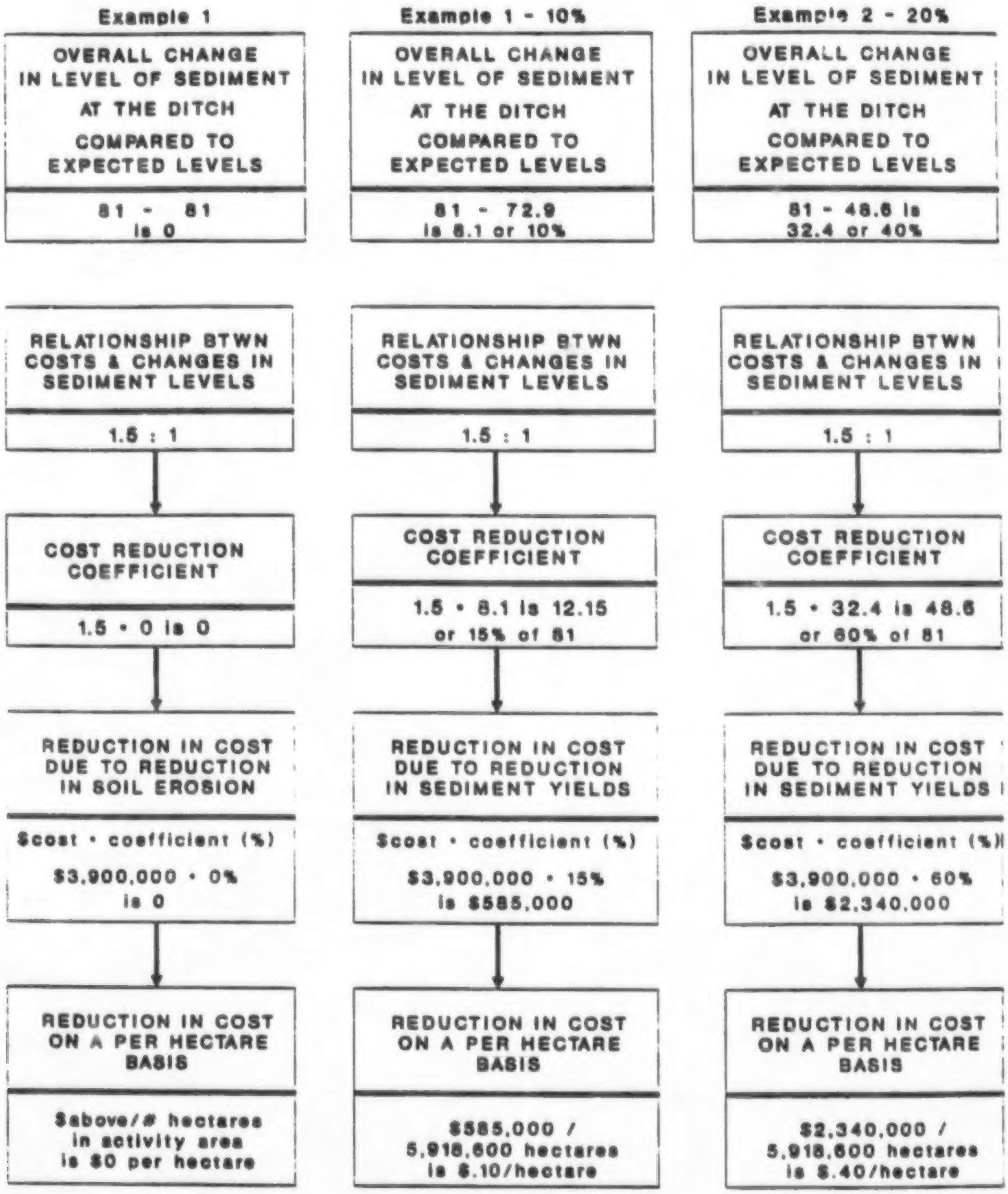
As for phosphorus, the impact on water conveyance systems is not significant and therefore will not be factored into the analysis.

7.2 WATER FLOW CONTROL

Sedimentation can make the damages of flooding 2 - 3 times greater along upstream stretches of a watershed, increasing both the volume and frequency of flooding (Clark *et al.*, 1985). However, the construction of sediment control measures upstream will help to reduce overall flooding by adjusting for increases in sediment deposits.

Despite control measures and even if soil erosion were eliminated, flooding would still remain a problem. The majority of the damages can be associated with phosphorus and sediment found within flood waters. For example, silt, sand and gravel from flood waters settle on fertile soils producing a loss in agricultural production downstream. As sediment settles, it destroys the crops ability to grow by covering the soil and the crop in a blanket of unfertile, contaminated and hard to penetrate silt. Because flooding is a natural event and the above situations will occur despite reductions in soil erosion, the damages (monetary) caused by flooding as a direct measurable impact of soil erosion is not included in the analysis.

Figure 7.1 Effect of Reductions in Sediment Yields on Water Conveyance Systems -Scenario A



One method for controlling sediment accumulation and flooding, is through the construction of dams or barriers across waterways forming a sediment control basin. The function of a sediment control basin is to retain run-off for a period of time, thereby allowing sediment to settle out. Reduced stream or river velocities result in more settling and possibly the formation of sand and vegetation bars.

Based on discussions with local conservation authorities in Southern Ontario, local reservoirs do not seem to be losing storage capacity at a rate that is noticeable. However, Dendy (1968) believes the deterioration of reservoirs caused by sediment accumulation is greater than most believe it to be. Based on Dendy's theory of sediment build-up in reservoirs, the cost of storage depletion of reservoirs as an input attributable to soil erosion from agricultural sources will be analyzed.

7.2.1 Storage Depletion

E. Dendy (1968) states that average sediment accumulation rates in reservoirs decrease as drainage area increases. Using the data from Table 7.1 we can assume that small reservoirs (0 -100 acre-feet capacity) will deplete their storage by about 3% per year, medium reservoirs (100-10,000 acre-feet) will deplete their storage capacity by 0.9% per year, and large reservoirs (10,000 - 1M acre-feet) only lose 0.3% of their capacity every year.

One way to respond to lost capacity is to anticipate the loss and build extra capacity to collect the sediment. Another alternative is to remove the sediment from the reservoir by dredging. Estimates of these costs indicate that they may be quite substantial. Using calculations on the cost of new storage from Clark *et al.* (1985), the expected impact can be anywhere from $300 to $700 per acre - foot, or 25 cents per cubic meter (we will use an average of $500 for new storage). Dredging is typically more expensive than creating new storage capacity at $1.25 per cubic yard ($2 per cubic meter in 1980 dollars), or $2,500 per acre-foot of material removed.

Table 7.1 Sedimentation of Reservoirs

Reservoir Capacity	# of Total Reservoirs (acre-feet)	Total Initial Storage Capacity (acre-feet)	Total Storage Depletion (acre-feet)	Individual Reservoir Storage Depletion (%/year)
0-10	161	685	180	3.41
10-100	228	8,199	1,711	3.17
100 - 1000	251	97,044	16,224	1.02
1000 - 10000	155	488,374	51,096	0.78
10000 - 100000	99	4,213,330	368,786	0.45
100000 - 1 M	56	18,269,832	634,247	0.26

Source: Ferris E. Dendy, "Sedimentation in the Nation's Reservoirs," Journal of Soil and Water Conservation, No. 23 (1968):137.

Based on an average size reservoir, at 5,000 acre-feet, the cost of dredging would be $12,500,000. In contrast, the cost to rebuild new storage would be $2,500,000, or one-fifth of the cost. Amortizing these values over a 110 year period (expected time in which a medium size reservoir will fill up at a rate of 0.9 percent/year), annual costs of $113,600 for dredging or $22,700 for new storage capacity will occur.

Figure 7.2 helps to explain how the effect of reduced soil erosion can be translated to reductions in costs to the farmer. For instance, if soil erosion is reduced by 20%, there will be a comparable reduction in total sediment leaving the farm and entering the ditch (see Chapter 5.0 for complete explanation). Given $113,600 is the water control cost associated with a sediment yield of 81 units, a 40% reduction in sediment yield would result in a reduction in costs of $54,520 (Scenario A) assuming a one to one relationship between costs and sedimentation reductions. Consequently, if the calculated hectare base for the

Figure 7.2 Effect of Reductions in Sediment on Water Flow Control - Scenario A

Base	Example 1 - 10%	Example 2 - 40%
OVERALL CHANGE IN LEVEL OF SEDIMENT AT THE LAKE COMPARED TO EXPECTED LEVELS	OVERALL CHANGE IN LEVEL OF SEDIMENT AT THE LAKE COMPARED TO EXPECTED LEVELS	OVERALL CHANGE IN LEVEL OF SEDIMENT AT THE LAKE COMPARED TO EXPECTED LEVELS
81 - 81 is 0	81 - 72.9 is 8.1 or 10%	81 - 48.6 is 32.4 or 40%
RELATIONSHIP BTWN COSTS & CHANGES IN SEDIMENT LEVELS	RELATIONSHIP BTWN COSTS & CHANGES IN SEDIMENT LEVELS	RELATIONSHIP BTWN COSTS & CHANGES IN SEDIMENT LEVELS
1 : 1	1 : 1	1 : 1
COST REDUCTION COEFFICIENT	COST REDUCTION COEFFICIENT	COST REDUCTION COEFFICIENT
1 * 0 is 0	1 * 8.1 is 8.1 or 10% of 81	1 * 32.4 is 32.4 or 40% of 81
REDUCTION IN COST DUE TO REDUCTION IN SOIL EROSION	REDUCTION IN COST DUE TO REDUCTION IN SOIL EROSION	REDUCTION IN COST DUE TO REDUCTION IN SOIL EROSION
$cost * coefficient $136,300 * 0% is 0	$cost * coefficient $136,300 * 10% is $13,630	$cost * coefficient $136,300 * 40% is $54,520
REDUCTION IN COST ON A PER HECTARE BASIS	REDUCTION IN COST ON A PER HECTARE BASIS	REDUCTION IN COST ON A PER HECTARE BASIS
$above/# hectares in activity area is $0 per hectare	$13,630 / 50,000 hectares is $.273/hectare	$54,520 / 50,000 hectares is $1.09/hectare

study area is 50,000 hectares, then the associated per hectare cost savings would be $1.09 per hectare. We can therefore conclude that the benefits to be gained by reducing soil erosion by 40%, could be $1.09 per hectare for water flow control alone.

7.3 DRINKING WATER TREATMENT

In order to ensure that water is safe for human drinking purposes, several steps must be taken to clean and purify the water of both sediment and contaminants such as phosphorus and pesticides. The MOE objective is that drinking water must be sediment free (value of 1 FTU for turbidity), and pleasing to the user (MOE, 1978).

7.3.1 Effect of Sediment and Phosphorus on Drinking Water

Water treatment plants typically receive their water supply from rivers with some degree of pollutants. For this reason, treatment plants must be furnished with equipment that can eliminate unwanted sediment, suspended and dissolved solids, and harmful chemicals in order to make the water suitable for human consumption.

In the case of suspended sediment (e.g., minerals and soil particles) found in surface water supplies, large settling bins, filtration, and chemical coagulants are used to speed up the settling process to withdraw unwanted particles. Excessively turbid water can increase the cost of water treatment up to 35 percent (Clark *et al.*, 1985). Maintenance costs will also increase as suspended sediment induces scaling and corrosion of the equipment required to purify the water. An additional cost will transpire due to an increase in turbidity which is expected to raise the chemical dosage required up to some turbidity level (Birch *et al.*, 1983). Although this is generally true, in some cases turbidity (clay) is added to assist the treatment process (Ken Roberts, correspondence).

Phosphorus is another contaminant that can have an impact on water treatment costs, although not directly. According to Jack Fraser, P. Eng. Windsor Utilities Commission, phosphorus contamination is not a major concern. The rationale behind this is that the majority of phosphorus is bound up in soil particles, and as such, is removed in the filtration and settling processes.

Despite this, excessive phosphorus loads can indirectly affect water treatment costs by increasing the amount of algae within rivers and lakes which then enter into the water treatment system. Other minor effects that might be expected as a result of sediment and phosphorus are algal toxins, taste and odour problems and pesticides on or associated with sediment. The additions of chemicals (i.e., powdered activated carbon) are often required to abate these problems.

Consequently, sediment and phosphorus loading will impact water treatment costs in a number of ways. These cost factors are identified as chemical costs, filtration costs and sludge disposal costs, and are examined more closely below.

7.3.2 Expected Cost Impact

According to Bardos *et al.* (1987), estimated changes in water treatment costs are affected by altering soil erosion rates. They found that water treatment costs will change by 0.4 percent for every 1.0 percent change in cropland soil erosion rates (based on data collected from upland watersheds in western Ohio). This is fairly consistent with Clark's (1985) estimate; that a 35% change in treatment costs would result from reductions in overall soil erosion. Therefore, the relationship (expressed as a coefficient) between both sediment and phosphorus levels and costs of water treatment is 1:0.4.

Using a cost structure consistent with Wall *et al.*, (1989) and MOE, operational costs for water treatment are approximately 40 cents per thousand gallons of treated water. Approximately 4 to 17 cents/thousand gallons of treated water

is attributable to erosion, 2 cents of which is spent on the removal of sedimentation from cropland (Wall *et al.*, 1989). Based on this estimate we will assume that another 2 cents is also spent on the removal of algae from filtration system due to phosphorus. This means that a total of 4 cents/thousand gallons or 10% of total operational costs can be attributed to cropland erosion.

An example of a water treatment facility exhibiting several of the problems mentioned above is the Dresden plant. However, at this time information is not available to describe the extent of the problems occurring.

Therefore another example of a water supply system, the Windsor Utilities Commission will be used for the analysis. The source of their water supply is the Detroit River which is a major outlet of Lake Huron. Two intake pipes allow the water to flow by gravity into the Deep Well of the lower lift in the pumping station. Travelling screens remove any coarse material (e.g., algae and coarse sediment) that may flow in with the water. At the pumping station, chemical additions of chlorine are added to kill bacteria. Iron deposits are then removed in the filtration process. The water is then treated with a coagulant (aluminum sulphate) before it enters settling basins where suspended particles coagulate and settle to the floor of the basins. The settled material is eventually discharged into waste sewers, then back into the river. From the settling bins, the water then passes into the filtration system consisting of 20 filters, underdrains, layers of sized gravel, graded sand, coal and washer troughs. At this stage the filtered water falls by gravity to the reservoir system.

After examination of the treated water, the level of turbidity is substantially decreased, and phosphorus is reduced from a high of 0.043 pm to relatively 0 pm (Fraser, 1989, and Windsor Utilities Commission, 1987). All of Windsor, St. Clair Beach, Sandwich South, Sandwich West and Tecumseh are served by the Windsor Utilities Commission encompassing an area of approximately 40,000 hectares. Water for both drinking and industrial purposes is treated in the same manner.

After the treatment process is complete, the Windsor Utilities Commission produces 159 million litres per day (or 35 million gallons per day) of treated drinking water (Fraser and Windsor Utilities Commission, 1987). If operational costs for treatment of the water are approximately 40 cents per thousand gallons treated (see above), the total operational costs for the Windsor Utilities would be $14,000 per day or $5,110,000 per year.

Using the above analysis and assumptions, 10% of the total treatment costs can be attributed to sediment or phosphorus loadings from cropland. The Windsor Utilities Commission will therefore incur operational costs of $1,400 per day or $511,000 per year in operational costs attributed to cropland erosion. As stated earlier, total phosphorus loads can be, to a large extent, associated with sediment. Therefore, we will assume 60 percent of the value stated will be due to sediment yields and the remaining 40 percent to phosphorus yields.

Utilizing estimated total sediment yields (we have assumed 81 units) and potential percentage reductions in soil erosion (e.g., 10 and 40 percent), we can begin calculating the total annual cost of sediment and phosphorus to water treatment facilities.

A typical water source used by communities is groundwater wells, although in terms of volume used in the province, lake derived surface water is predominant. The change in sediment levels (32.4 units or 40%) and phosphorus levels (19.4 units or 12%) at the lake must be multiplied by the sediment and phosphorus cost reduction coefficients (1 : 0.4) specific to water treatment. This will determine the value to be used to express the cost benefits arising from given reductions in sediment and phosphorus. Figures 7.3 and 7.4 explain this in more detail.

The expected cost savings associated with an overall 40% decrease in sediment and phosphorus yields (Scenario A) is $49,056 and $19,622 respectively. This equates to a per hectare benefit of $2.12 for sediment and 85 cents for phosphorus reductions.

Figure 7.3 Effect of Reductions in Sediment Yields on Drinking Water Treatment Facilities - Scenario A

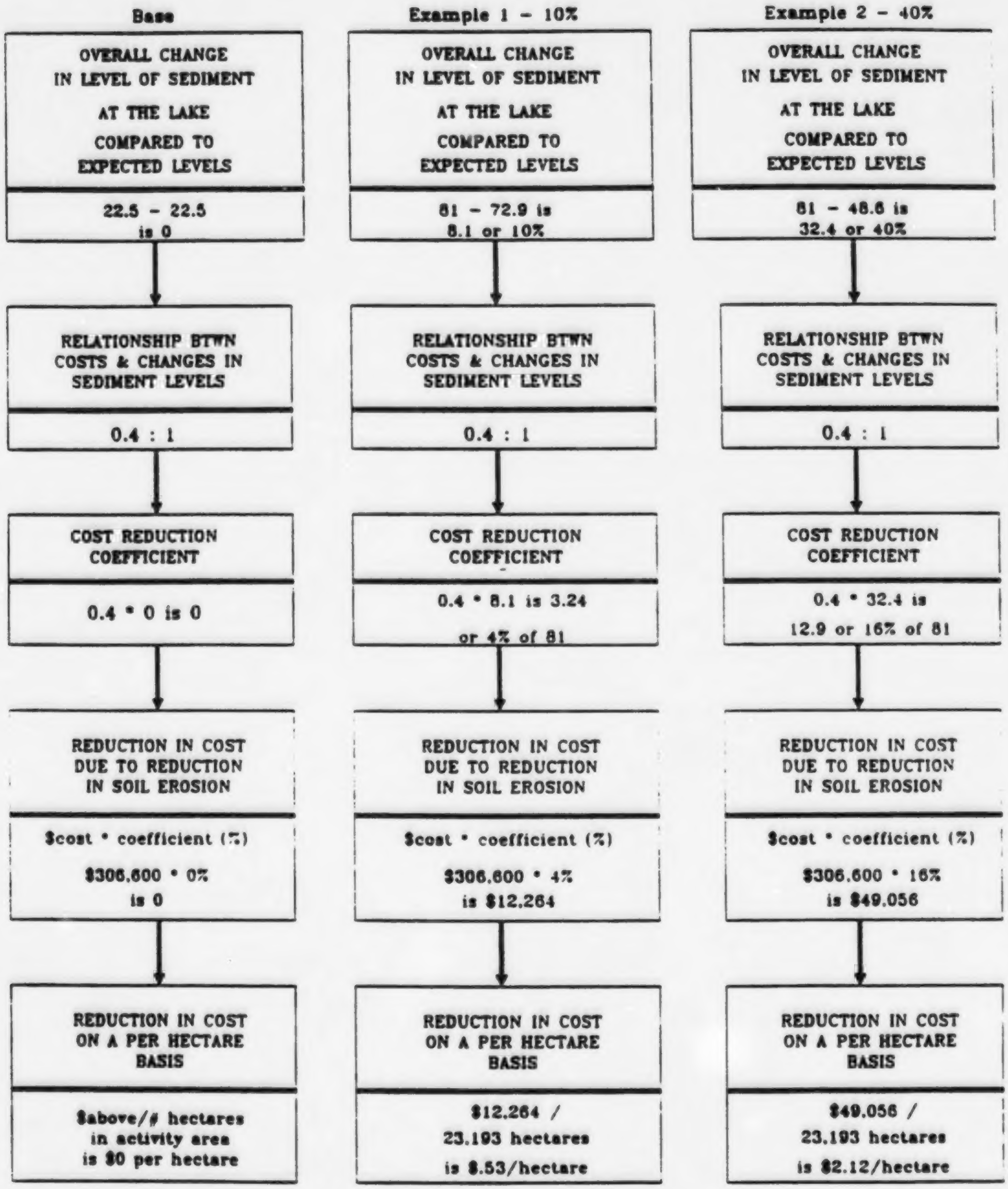
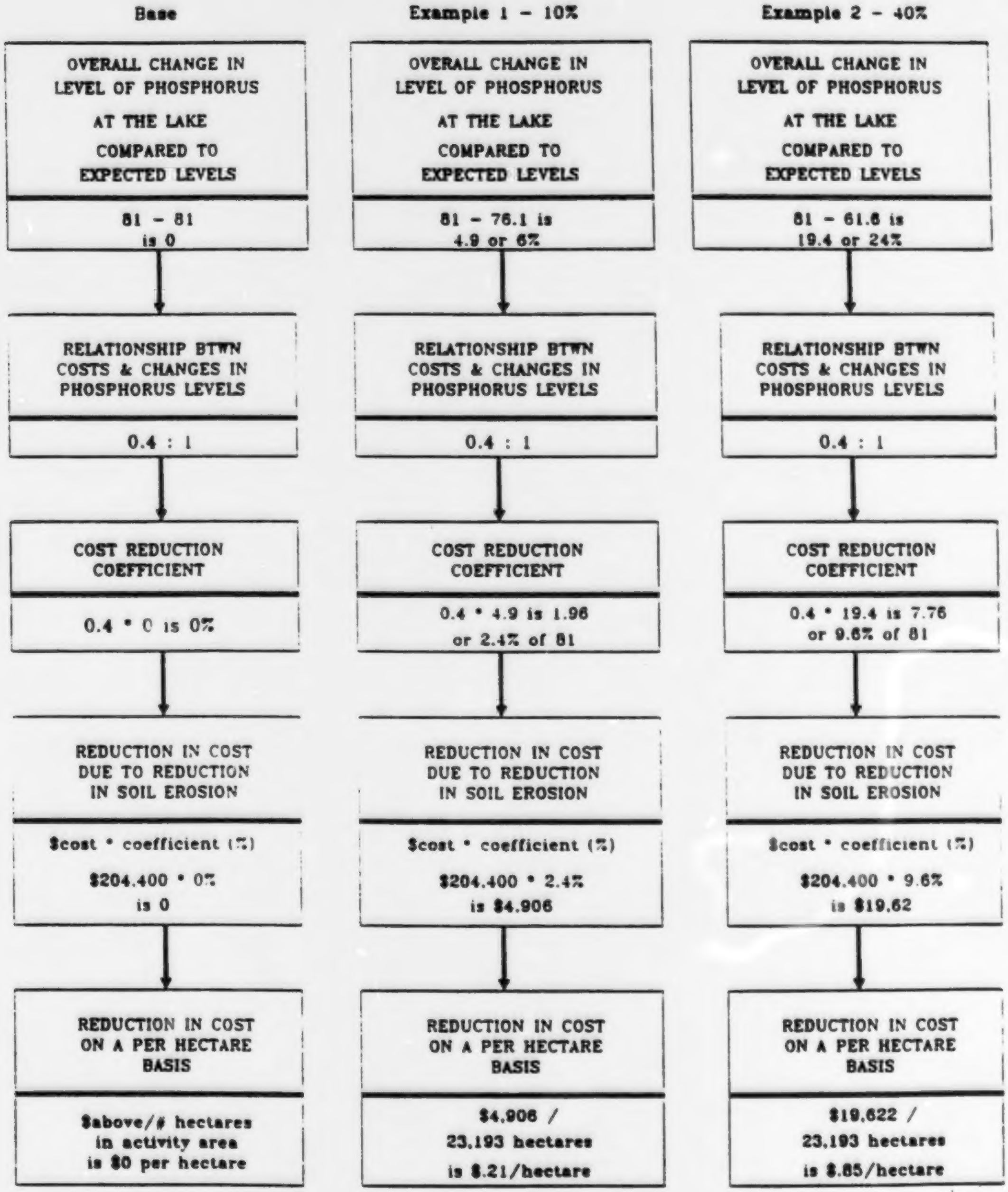


Figure 7.4 Effect of Reductions in Phosphorus Yields on Drinking Water Treatment Facilities - Scenario A



7.4 WATERSHED AUTHORITIES

The damage of soil erosion to conservation authorities facilities can be quite extensive. Factors that must be taken into consideration include activities such as the depletion of water storage facilities, flooding damages and water quality problems that affect swimming, boating and recreational fishing facilities. The sum of which has been analyzed to a large extent in previous and upcoming sections. As a result, no estimates on a dollar figure have been obtained or utilized to express the influence of soil erosion on watershed authorities as a separate activity. The non-priced recreational activities that follow will give a clearer understanding of how watershed recreational activities may be affected by agricultural soil erosion.

8.0 RECREATIONAL ACTIVITIES

Aquatic ecosystems can be seriously affected by sediment and other erosion related contaminants in complex ways. Some biological impacts are reflected in damage estimates to recreational fishing or swimming, but little is known about the overall magnitude of these impacts. Moreover, there is no commonly accepted method for estimating their cost. The absence of an overall cost estimate of damages to biological communities does not mean that the impacts are small. They are not. "If there were appropriate means for placing economic values on these damages, this category might well outweigh any of the other," (Clark, 1985).

8.1 SWIMMING

In Ontario, the Ministry of Health is responsible for the monitoring and evaluation of water quality at most public beaches to ensure safety for swimmers and bathers. The basis of evaluation is the Ministry of Environment guideline. The guideline for safe bathing and swimming states that if consecutive water samples exceed 100 faecal coliform bacteria or 1000 total bacteria per 100 ml of water, the beach area will require a pollution warning (posting) to prevent public use (MOE, 1984). In addition, beach users are also warned when high turbidity levels and more frequently when heavy algae growth, particularly dense blue-green algal blooms from phosphorus nutrient enrichment, occur.

A "Rural Beaches Program" has been established by the Ontario Ministry of Environment to deal with beaches where the main pollution source is rural. The MOE carries out its beaches program within the 38 conservation authorities situated throughout Ontario. With cooperation from the authorities, this regional approach has provided an efficient way to trace the sources of the pollution while developing a 'Clean Up Rural Beaches' (CURB) plan specific to an individual watersheds' problems and needs.

To evaluate the relative significance of individual source types of pollution (e.g., phosphorus and sediment), estimates of individual components of the total loadings are required. For phosphorus, this involves examining the concentration of the contaminant source within the run-off. As well, the proportion of this run-off which enters the stream system is also measured. Phosphorus being an input that results from specific run-off events or spills is referred to as a pulse input according to Boss *et al.*, 1989.

The MOE phosphorus guideline defined to prevent excessive plant growth in streams and rivers is 0.03 mg/litre or 0.02 mg/L where waters enter a lake or standing body of water (MOE, 1984). Total phosphorus concentrations tend to be lower upstream of agricultural lands (Hocking, 1989) while peak concentrations of phosphorus and sediment appear coinciding with heavy rainfalls, manure irrigation, and spring run-off (Hocking, 1989).

The revised Great Lakes Water Quality Agreement of 1978 (IJC, 1988) has established future phosphorus loads for Lake Huron at 2,800 metric tonnes (m.t.) per year. This represents a 200 m.t. per year reduction from the 1976 base loadings of 3,000 per year (Hocking, 1989).

Despite reductions in phosphorus loadings, beach closures across the province have continued to cause millions of dollars in damages to many resort communities (Burger, 1975), some of which is attributable to phosphorus associated problems such as algae blooms, water odour and taste problems.

8.1.1 Phosphorus Delivery to Beaches

In the case of the Ontario Rural Beaches study by Boss *et al.* (1989), 100% in-stream phosphorus delivery to the beach was assumed. This is an over simplification, but excessive phosphorus inputs to a stream will have negative impacts whether in-stream *en route* to a downstream beach or at the beach itself. In the short run, such simplifications may result in over-estimates of phosphorus cost reduction ratios. By using the scenarios discussed in Chapter

5.0 we can obtain a more accurate range of estimates dealing with reductions in phosphorus.

Although approximately one-third of the total phosphorus load to Pittock and Wildwood Reservoirs can be attributed to waste effluent, the largest single source of phosphorus is agricultural soil erosion (an event-flow input) accounting for approximately one-half of total annual phosphorus loads to the reservoirs in the study (Bos *et al.*, 1989). Other studies have found that agricultural erosion contributes 65 percent of total phosphorus loads to Ontario rivers and streams (Mason, 1980).

Assuming agricultural soil erosion accounts for approximately 50% of phosphorus loads to rivers and lakes, the most cost effective solution to control phosphorus related problems would be improvement of farming practices to prevent soil erosion and secondly, control of waste effluent from milkhouses and industrial discharges.

To determine the economic cost associated with beach closure, some of which can be contributed to on-farm erosion, the number of recreational users turned away due to sediment and phosphorus pollution can be assessed (visitation model). This can be measured as the length of time during the year that Ontario beaches were closed due to water quality problems.

8.1.2 Phosphorus - Its Effect on Fanshawe Reservoir Beach

Many of the water quality problems in the Fanshawe, Pittock and Wildwood Reservoir Watersheds stem from several sources:

1) livestock access;
2) milkhouse washwater;
3) household septic systems; and
4) agricultural soil erosion.

Using beach closures as an indicator of water quality (soil erosion being one of the causes of poor water quality), the economic benefits that can be achieved through improved water quality can be determined.

Calculations of the total annual decline in attendance over a ten year period at the Fanshawe Reservoir beach, attributes 49% of beach closures to poor water quality (Bos and *et al.*, 1989). A percentage of these closures, (assume 50%) are due to algae growth caused by excessive phosphorus. The largest single source of phosphorus is agricultural soil erosion, accounting for one-half of the total annual loads. Therefore, we can approximate the overall effect of phosphorus from cropland sources on attendance to be 12.3% (49% x 50% x 50%) - see Table 8.1 below.

Table 8.1 Estimated Beach Users Response to Changes in Water Quality[1]/Household

Water Quality Rating	Average Number of Beach Trips per Season	Average Consumer Surplus for Beach Use
1 - Very Poor	4.2	$ 101
2 - Poor	5.4	$ 118
3 - Fair	7.0	$ 135
4 - Good	9.0	$ 155
5 - Very Good	11.5	$ 179

Source: Ecologistics, 1990.

[1] Based on regression analysis of a survey of beach goers at Kelso Conservation Area, Rockwood Conservation Area, Fifty Point Conservation Area, Guelph Lake Conservation Area and Sunnyside Beach.

Given an improvement in water quality, the individual households currently using the beach would respond by increasing seasonal trips frequencies from

5.4 (poor) to 7.0 times (fair conditions). This would result in a $17 annual consumer surplus. These results can be used to estimate the aggregate benefit associated with increasing demand for beach trips. However, the analysis must take into account the substitution effect between sites as one beach improves and another does not. Water quality improvements should therefore both redistribute beach use activity (substitution effect) and take into account the overall increased use (net growth in demand).

Demand data obtained from Usher *et al.*, (1981) gravity model will help to establish an annual beach value per household. This is based on the number of user households, which is equivalent to the number of beach visits divided by the visits per household multiplied by the number of persons per household.

- # of user households = # beach visits / visits per household * person per household

Usher has estimated this value to be 2.9 user households. For a beach with fair quality and providing 20,000 individual user days of recreations, the estimated number of users would be (20,000 users / (2.9 households * 7 numbers of beach trips per season)) or 985. The total annual consumer surplus associated with their use of the beach would be 985 users x $135 or $132,975 per year. An improvement in water quality to a rating of good would increase consumer spending by $19,700 (985 x (155 - 135)).

There are 1,300 provincially monitored beaches in Ontario (Bos *et al.*, 1989). If one-half of them exhibited an improvement in water quality from fair to good, 25 percent of which could be associated with phosphorus related problems (e.g., algae blooms and odour problems) then the benefit to agriculture would be:

- (($19,700 * 25%) * (50% * 1300) = $3,201,250

Following the analysis in Figure 8.1, we realize that the benefit of improvements in phosphorus yields to recreational facilities could be approximately 11 cents per hectare.

8.1.3 Sediment Related Accidents

High levels of suspended sediment can create other, less direct costs to the economic community. Sediment is responsible for some related turbidity problems which decrease the transparency of a previously clear water body. Decreasing the clarity of the water can create unseen hazards (murkiness) for the recreational swimmer - turbid water acts to obstruct the divers view of any unseen submerged hazards. These hazards account for many swimming accidents each summer. The number of deaths or accidents attributable to unseen hazards are not documented by conservation authorities.

However, data on the causes of recreational accidents suggest that turbidity could be a factor in a number of deaths, perhaps hundreds of the 7,000 or so drownings experienced in the U.S. annually (Clark *et al.*, 1985). For every death it is quite common to place a value of $1 million and for every serious accident a value of 50% of a death can be used (Clark *et al.*, 1985).

Therefore, it is evident that suspended sediment can potentially be linked to numerous deaths and swimming accidents and as a result so to can there be a value assigned to these. However, to suggest an exact figure would be tenuous. It is therefore concluded that this kind of evaluation is beyond the scope of this analysis.

8.2 BOATING

In the case of sedimentation, reductions in the capacity of harbour facilities and navigation channels can create hazardous situations, especially to an individual uneducated in the ways of boating and water safety. As navigation channels become narrower and shallower the number of boating accidents increases.

Figure 8.1 Effect of Reductions in Phosphorus on Recreation Swimming - Scenario A

Base	Example 1 - 10%	Example 2 - 40%
OVERALL CHANGE IN LEVEL OF PHOSPHORUS AT THE LAKE COMPARED TO EXPECTED LEVELS	OVERALL CHANGE IN LEVEL OF PHOSPHORUS AT THE LAKE COMPARED TO EXPECTED LEVELS	OVERALL CHANGE IN LEVEL OF PHOSPHORUS AT THE LAKE COMPARED TO EXPECTED LEVELS
81 - 81 is 0	81 - 76.1 is 4.9 or 6%	81 - 61.6 is 19.4 or 24%
RELATIONSHIP BTWN COSTS & CHANGES IN PHOSPHORUS LEVELS	RELATIONSHIP BTWN COSTS & CHANGES IN PHOSPHORUS LEVELS	RELATIONSHIP BTWN COSTS & CHANGES IN PHOSPHORUS LEVELS
1 : 1	1 : 1	1 : 1
COST REDUCTION COEFFICIENT	COST REDUCTION COEFFICIENT	COST REDUCTION COEFFICIENT
1 * 0 is 0	1 * 4.9 is 4.9 or 6% of 81	1 * 19.4 is 19.4 or 24% of 81
REDUCTION IN COST DUE TO REDUCTION IN SOIL EROSION	REDUCTION IN COST DUE TO REDUCTION IN SOIL EROSION	REDUCTION IN COST DUE TO REDUCTION IN SOIL EROSION
$cost * coefficient (%) $3,201,250 * 0% is 0	$cost * coefficient (%) $3,201,350 * 6% is $192,075	$cost * coefficient (%) $3,201,250 * 24% is $800,313
REDUCTION IN COST ON A PER HECTARE BASIS	REDUCTION IN COST ON A PER HECTARE BASIS	REDUCTION IN COST ON A PER HECTARE BASIS
$above/# hectares in activity area is $0 per hectare	$192,075 / 7,676,960 hectares is $.03/hectare	$800,313 / 7,676,960 hectares is $.11/hectare

Over the 1980 - 1987 study period, the Ministry of Natural Resources estimated that 695 people perished in recreational boating accidents in Ontario (MNR, v). The eight year average being 87. Although there is no definite trend in the number of deaths, the largest group tends to be between the ages of 15 and 34. A small number of these fatalities involved boater negligence.

However, determining the number of fatalities as a consequence of suspended sediment would be weak at best and therefore beyond this analysis.

A lack of statistics relating dollar values to the damage created by boating accidents (caused by turbidity and/or sediment) restricts us from following up with a value to use in the economic analysis. Therefore, as the charts in Chapter 10 indicate, dollar values as related to reductions in soil erosion are unavailable (unknown).

8.3 SPORT FISHING

Published results from the National Surveys of Sportfishing, 1985 clearly demonstrate the importance of recreational fishing. Ontario's recreational fisheries contribute to the nation's social and economic development. Over three million Ontario anglers fished for a total of 34.4 million days in marine and inland waters in 1985. They spent $981.2 million on activities and supplies directly connected with their sport, and an additional $782.4 million on equipment attributed to sport fishing activities (Ministry of Natural Resources, 1985).

In 1985, Canada was host to seven million anglers, six million of which were Canadians, who spent a total of $4.7 billion on recreational fishing and fishing gear every year (Canada, Dept. of Fisheries - Conference, 1988). In Ontario, the importance of recreational fishing may be even greater than the rest of the country. Primarily because Ontario has no large commercial coastal fishing facilities. As a result, Ontario is host to almost two-thirds of all non-Canadian anglers visiting this country (Canada, Dept. of Fisheries - Conference, 1988).

Ontario also supplies 41 percent of all fish caught by anglers in this country (Canada, DofF, 1988). Therefore, recreational fishing should be nationally recognized as having a sizable economic contribution.

The recreational fishery industry of Ontario is one of major importance. In 1985, anglers caught an estimated 144.1 million fish of all species and retained 74.4 million of them (Table 8.2). Smelt, perch and walleye were the most widely taken species, accounting for 64% of the harvest by number. Walleye, trout and bass, in order of priority were the species most sought after by resident and non-resident anglers.

The numbers shown in Tables 8.2 and 8.3, while indicating the importance of sport fishing should be used with caution. Angler expenditures do not necessarily represent the value of the sport fishing resource or the value of the recreation provided by it. Economists most often use a "willingness to pay" method to estimate the value people place on outdoor recreational activities (MNR, 1985). This value is over and above the actual cost incurred by the recreational participant to enjoy the activity.

Table 8.4 shows the results of the 1985 Ontario Sport Fishing Survey. Active resident anglers were asked at what daily cost would they have decided not to fish if costs had been higher due to increased costs in gasoline, accommodation etc. Twenty-one percent indicated they would not be willing to pay additional costs. Up to 64% said they would be willing to pay up to \$10 and 82% indicated they were willing to pay up to \$20. The total "willingness to pay" was \$490.6 million.

Table 8.2 Numbers of Fish Caught and Retained by Species in Ontario in 1985

Fish Species	Resident	Nonresident	Total
Smelt	16,658,776	616,844	17,275,620
Perch	12,025,263	4,677,755	16,703,018
Walleye	8,500,662	4,896,811	13,397,473
Smallmouth Bass	3,898,585	1,298,735	5,197,320
Panfish	1,504,252	3,602,233	5,106,485
Pike	2,663,173	2,159,915	4,823,088
Brook Trout	1,968,473	82,707	2,051,180
Largemouth Bass	1,584,761	432,225	2,016,986
Lake Trout	1,702,604	216,056	1,918,660
Rainbow Trout	1,324,399	22,569	1,346,968
Whitefish	474,048	69,920	543,968
Chinook	466,636	9,433	476,069
Coho	280,572	8,555	289,127
Brown Trout	236,508	9,881	246,389
Maskinonge	71,490	16,629	88,119
Other Species	2,530,811	380,146	2,910,957
Total Number Retained	55,891,013	18,500,414	74,391,427
Weight of Fish Kept (in lbs)	63,081,001	25,379,655	88,460,656

Source: Ministry of Natural Resources, Ontario Sport Fishing Survey, 1985.

Table 8.3 Distribution of Species Preferences Indicated by Anglers in Ontario in 1985

Fish Species	Resident	Nonresident	All Anglers
Walleye	26.7	37.5	29.8
Trout	28.3	8.9	22.7
Bass	21.8	19.4	21.1
Northern Pike	8.9	23.4	13.1
Perch	6.3	4.8	5.9
Maskinonge	2.3	3.0	2.5
Salmon	3.3	0.4	2.5
Lake Whitefish	0.7	0.3	0.6
Panfish	0.2	1.0	0.5
Smelt	0.5	0.3	0.4
Catfish	0.4	0.1	0.3
Bluegill	0.1	0.4	0.1
Other Species	0.5	0.5	0.5
Total	100.0	100.0	100.0

Source: Ministry of Natural Resources, Ontario Sport Fishing Survey, 1985.

Table 8.4 Willingness of Active Residents Anglers to Pay Additional Costs for Fishing in Ontario in 1985

Additional Cost Per Day	% of Active Anglers	Willingness to Pay
$0.00	21.3	0
up to $1.00	3.5	107,100
up to $2.00	1.3	80,000
up to $3.00	1.8	165,300
up to $4.00	1.9	233,000
up to $5.00	9.9	1,515,200
up to $7.50	2.0	460,000
up to $10.00	22.2	6,795,400
up to $20.00	17.6	10,774,700
up to $30.00	8.0	7,346,400
up to $40.00	3.1	3,795,000
up to $50.00	3.5	5,357,000
up to $100.00	3.9	11,938,000
Additional Annual Amount	100.0	$490,550,000*

*Number may not add due to rounding.
Source: Derived from Sport Fishing Survey in Ontario, 1985.

Unlike the commercial fishing industry where market values for fish can be determined by the weight (ton) of fish harvested, recreational sport fishing is usually measured by expenditures utilized to sport fish (or economic value of angling/harvesting days, willingness to pay). The best measure being the number of angler days per year available for sport fishing opportunities. The end product represents the value fishermen receive, and the enjoyment of the fishing experience itself.

To determine the effect that excessive sediment has on the sport fishing industry, we must look at how it affects the industry. Sediment can directly affect fish in many ways. It can cover or obscure food sources and hiding places. If the bed load is deep enough, nesting sites and habitats for plant roots are destroyed and breeding sites are smothered, interfering with normal hatching processes; the overall effect being a significant drop in fish and plant populations. The most preferred and popular sport fish (i.e., walleye, trout, bass and pike) are, unfortunately, also the fish most negatively affected by excessive sediment (MNR, 1981).

There is also a relationship between water turbidity and angling opportunities. Reduced visibility prevents fish from actually seeing lures. As the distance at which the fish can see the lure increases, the probability (success) of catching a fish decreases. One study indicates that the percentage reduction in the rate at which fish are caught is approximately proportional to the percentage reduction in visibility (Clark, 1987). In other words, turbidity and the rate at which fish are caught have an almost perfectly negative relationship.

One such example of the way the sport fish industry can be affected by pollution and excess sediment is found in the salmon industry. Hour for hour of fishing opportunity, salmon are the most valuable sportfish in Canada. When one looks at the numbers of people involved, salmon fishing makes up a relatively small share of sportfishing in Canada (Canada, Dept. of Fisheries - Conference, 1988). This occurs because there are not many salmon around. Salmon and their habitat have been negatively affected over the last century by sediment, pollution and other environmental problems.

8.3.1 The Cost of Cropland Sediment to Sport Fishing in Southern Ontario

Based on calculations of the number of fish caught for sediment-sensitive species reported by the Erosion and Sedimentation Control Committee (1983), we can calculate the effect of sediment on fish populations and the resulting economic value of an increased fish population. An estimate of the total annual cost of cropland sedimentation to the sport fishing industry in Southern Ontario is presented in Table 8.5. Based on an application of the idea that sediment affects certain fish species in different degrees, the Erosion and Sedimentation Control Committee, "estimated the potential percentage increase in fish populations that may result from the elimination of excess sediment to waterways," (Dickson *et al.*, 1988).

For example, a sediment factor of 1.0 for brook trout suggests that an elimination of excess sediment would result in the brook trout population doubling. The sediment factor multiplied by the initial number of fish caught represents the potential increase in fish if sediment did not pose a problem. Use of angler days is also important in calculating the value or willingness of fishermen to pay for the sport. The potential increase in the number of angler days (see column 6, Table 8.5) assumes that a 1.0 percent increase in the number of fish caught will lead to a 0.25 percent increase in the number of angler days (Dickson, 1988). A study by Russell and Vaughan (1982) suggested that a 1.0 percent increase in the number of warm water game fish caught would lead to a 0.33 percent increase in the number of angler days.

Column 9 represents that portion of the total potential number of fish caught, taking into account that there are a limited number of angler days available. Therefore, the potential increase in number of fish caught must be subtracted from the fish caught during the extra days. Column 10 then adds the fish caught in Ontario (column 1) to the fish caught with the extra days subtracting the potential remaining increase (column 9) as a ratio. Estimates on the value or willingness to pay ($18) for a day of recreational fishing (column 11) were also obtained from the Erosion and Sedimentation Control Committee, adjusted

for inflation. This is consistent with the $20 suggested by the Ontario Sport Fishing Survey. These values were used to determine the values of the extra fish being captured (column 12).

Combining the increase in angler day value with the value of the increase in participation, and summing for each species as in column (13), gives an estimate of the total benefits resulting from the elimination of excess sediment from streams and lakes in Southern Ontario. Dickson and Wall assumed that all excess sediment originates from cropland erosion, but since sediment found in lakes accounts for only 33% (Ribaudo, 1988), we will assume that 33% of the total $35 million is attributable to cropland erosion. Using 33% of this value, we can therefore say that $11.55 million is the total cost of cropland sediment to the recreational fishing industry.

Figures 8.2 and 8.3 have attributed $0.95/ha for sediment and $0.03/ha for phosphorous to a 10 percent reduction in soil erosion. Therefore, by reducing upstream pollutants, aquatic organism both upstream and downstream will greatly benefit, and the farmer can save the fishing industry approximately $1/ha of farm land just by reducing the amount of erosion occurring on the farm.

Table 8.5 Calculation of Total Annual Cost of Cropland Sedimentation to Sport Fishing in Southern Ontario (Resident Fishermen Only)

SPECIES	NO. FISH CAUGHT IN SOUTHERN ONTARIO BY SPECIES 1985 (000'S)	SEDIMENT FACTOR	POTENTIAL INCREASE IN NO OF FISH CAUGHT	AVERAGE CATCH PER DAY	CURRENT ANGLER DAYS	INCREASE IN ANGLER DAYS	NO OF FISH CAUGHT WITH EXTRA DAYS	TOTAL ANGLER DAYS	REMAINING INCREASE IN FISH CAUGHT	INCREASE IN CATCH PER DAY AS A PERCENT OF CURRENT	FISHING VALUE AT PREVIOUS CATCH RATES	INCREASE IN VALUE	TOTAL INCREASED VALUE
	1	2	3 [(1)x(2)]	4	5 (1)/(4)	6 (3)*0.25/(2)	7 (6)*(4)	8 (5)+(6)	9 (3)-(7)	10 (9)/(1)+(7)	11 (8)*$18	12 (11)*(10)*.125	13 (6)*$18+(12)
Bass - smallmouth	2,549,000	0.75	1,911,750	2.857	892,195	167,286	477,938	1,059,481	1,433,813	0.47	19,070,660	1,129,104	4,140,341
largemouth	1,412,000	0.25	353,000	2.857	494,225	30,889	88,250	525,114	264,750	0.18	9,452,040	208,302	764,304
Northern Pike	1,715,000	0.25	428,750	2.0	857,500	53,594	107,188	911,094	321,562	0.18	16,399,688	368,738	1,336,443
Rainbow Trout	1,075,360	0.75	806,520	0.5	2,150,720	403,280	201,630	2,553,980	604,890	0.47	45,971,640	2,722,005	9,980,681
Brook Trout	1,454,400	1.00	1,454,400	2.0	727,200	181,800	363,600	909,000	1,090,800	0.60	16,362,000	1,227,150	4,499,550
Brown Trout	180,000	1.00	180,000	1.0	180,000	45,000	45,000	225,000	135,000	0.60	4,050,000	303,750	1,113,750
Lake Trout	284,200	1.00	284,200	0.5	568,400	142,100	71,050	710,500	213,150	0.60	12,789,000	959,175	3,516,975
Whitefish	155,000	0.50	77,500	1.0	155,000	19,375	19,375	174,375	58,125	0.33	3,138,750	130,781	479,531
Walleye	5,412,000	0.50	2,706,000	2.0	2,706,000	338,250	676,500	3,044,250	2,029,500	0.33	54,796,500	2,283,188	8,371,688
Muskellunge	108,000	0.25	27,000	0.5	216,000	13,500	6,750	229,500	20,250	0.18	4,131,000	91,125	334,125
TOTAL	14,344,960										$186,164,283	$9,416,616	$34,527,394

Source: Dickson and Wall, An Economic Assessment of the Distribution of Benefits Arising from the Adoption of Conservation Tillage Practices in Crop Production in Southern Ontario, 1988

#2 The sediment factor - shows the potential % increase in fish populations that may result from elimination of excess sediment from waterways. Only those fish sensitive to sediment were included in the analysis.

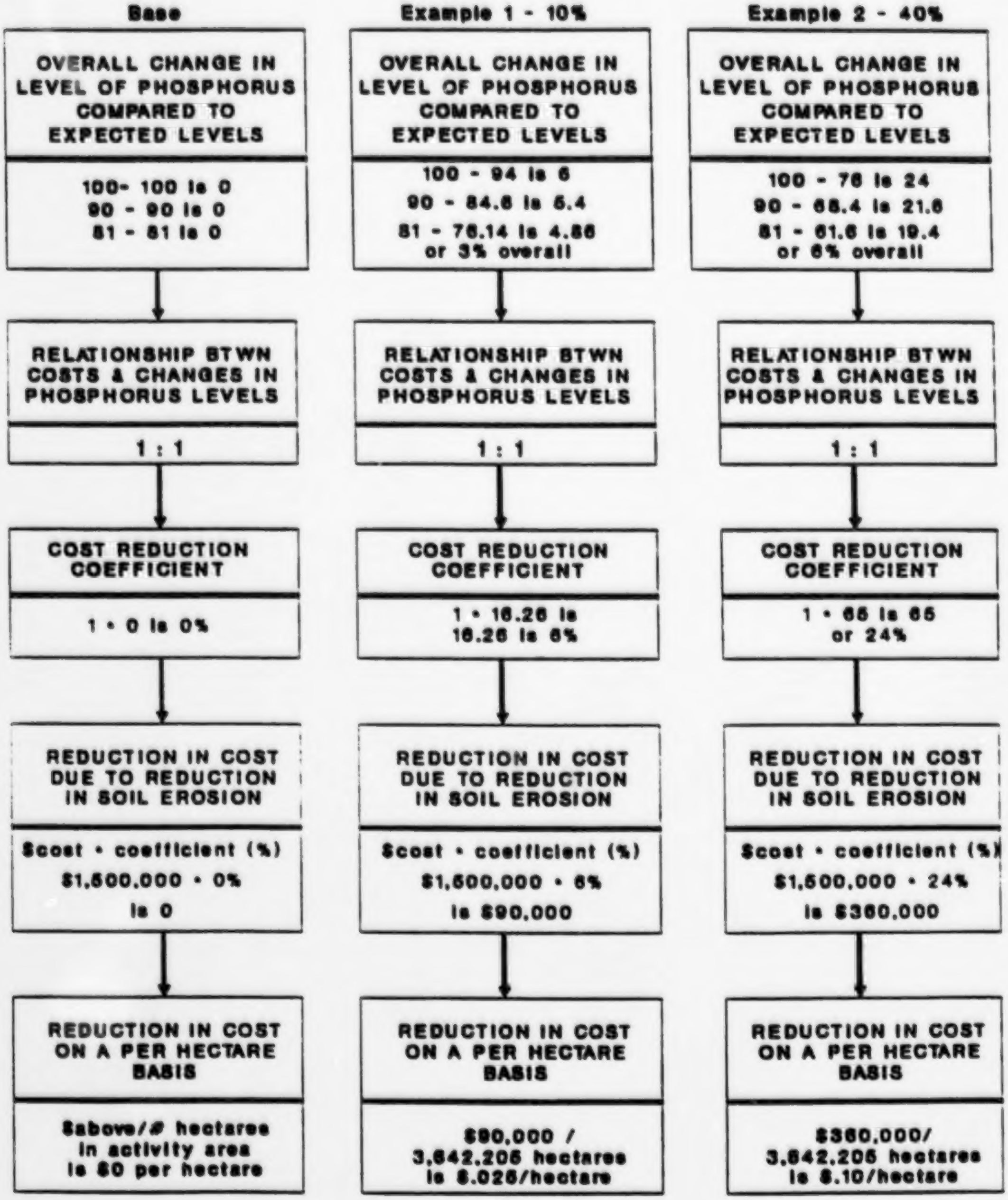
#4 As reported by the Erosion and Sedimentation Control Committee (1983)

#6 According to Dickson and Fox - a 1% increase in the number of fish caught will lead to a .25% increase in the number of angler days

Figure 8.2 Effect of Reductions in Sediment on Recreational Fishing - Scenario A

Base	Example 1 - 10%	Example 2 - 40%
OVERALL CHANGE IN LEVEL OF SEDIMENT AT ALL LEVELS COMPARED TO EXPECTED LEVELS	OVERALL CHANGE IN LEVEL OF SEDIMENT AT ALL LEVELS COMPARED TO EXPECTED LEVELS	OVERALL CHANGE IN LEVEL OF SEDIMENT AT ALL LEVELS COMPARED TO EXPECTED LEVELS
100 - 100 is 0 90 - 90 0 81 - 81 is 0	100 - 90 is 10 90 - 81 is 2.2 81 - 72.9 is 8.1 or 10% overall	100 - 60 is 40 90 - 54 is 36 81 - 48.6 is 32.4 or 40% overall
↓	↓	↓
RELATIONSHIP BTWN COSTS & CHANGES IN SEDIMENT LEVELS	RELATIONSHIP BTWN COSTS & CHANGES IN SEDIMENT LEVELS	RELATIONSHIP BTWN COSTS & CHANGES IN SEDIMENT LEVELS
1 : 1	1 : 1	1 : 1
↓	↓	↓
COST REDUCTION COEFFICIENT	COST REDUCTION COEFFICIENT	COST REDUCTION COEFFICIENT
1 • 0 is 0%	1 • 27.1 is 27.1 or 10% overall	1 • 108.4 is 108.4 or 40% overall
↓	↓	↓
REDUCTION IN COST DUE TO REDUCTION IN SOIL EROSION	REDUCTION IN COST DUE TO REDUCTION IN SOIL EROSION	REDUCTION IN COST DUE TO REDUCTION IN SOIL EROSION
$cost • coefficient (%) $34,527,951 • 0% is 0	$cost • coefficient (%) $34,527,951 • 10% is $3,452,795	$cost • coefficient (%) $34,527,951 • 40% is $13,811,180
↓	↓	↓
REDUCTION IN COST ON A PER HECTARE BASIS	REDUCTION IN COST ON A PER HECTARE BASIS	REDUCTION IN COST ON A PER HECTARE BASIS
$above/# hectares in activity area is $0 per hectare	$3,452,795 / 3,642,205 hectares is $0.95/hectare	$13,811,180 / 3,642,205 hectares is $3.79/hectare

Figure 8.3 Effect of Reductions in Phosphorus on Recreational (Sport) Fishing - Scenario A



8.3.2 Phosphorus

The other factor to be examined in relation to the industry of sport fishing is phosphorus. High phosphorus levels found in recreational fishing areas mean more nutrients available for uptake by algae. As algae grows and decomposes it depletes the level of dissolved oxygen. As oxygen levels decrease, fish and other organisms are depleted of the oxygen needed for survival. This results in a decrease in the population of game fish (i.e., trout, bass). Fewer fish means fewer opportunities for the game fisherman.

No estimates were obtained, as of yet, for a dollar value that can be attributed to the damage produced by excessive phosphorus loading from agricultural sources.

8.4 WILDLIFE AND NATURAL AESTHETICS

This section briefly reviews the impact that agricultural related pollutants have on the quality of wildlife and natural aesthetics.

8.4.1 Natural Aesthetics

Most water-related recreational activities involve swimming, boating or fishing. But they also involve people picnicking, walking or playing near water. In such cases, turbidity and sedimentation can cause less direct harm than occurs for swimmers. Nevertheless, the quality of the recreational experience is diminished. Moreover, the aggregate impact on less attractive water bodies may be very high because so many people are affected. A Louis Harris poll in 1983 reported that 74 percent of all Americans rated curbing water pollution as very important (U.S. Geological Survey). This attitude partially reflects a fear of the health effects that can result from exposure to toxic contaminants and other pollutants. But it also undoubtedly reflects a basic desire for clean rather than turbid, polluted water.

8.4.2 Wildlife and Wildlife Activities

According to Environment Canada (1989), Canadians spent approximately $5.1 billion on various wildlife-related activities in 1987. Wildlife Organizations accounted for $73.5 million; maintenance, improvements, or purchases of natural areas accounted for $1,291 million; residential activities accounted for $325 million; non-consumptive trips accounted for $2,233 million; incidental wildlife encounters another $117 million; and game hunting reported $1,060 million in expenditures. Average expenditures per participant for primary non-consumptive wildlife-related trips and outings in Ontario in 1987 were $30 per day or $485 per year.

Other indirect cost that may be related to costs associated with inputs from rural and agricultural sources include:

a) cost of managing rivers and lakes in order to maintain their productivity;
b) cost (per kilometre) of rehabilitating creeks due to cattle access problems, excessive bedloads etc.; and
c) wetland restorations costs.

According to expert opinion, 60 percent of the degradation of natural habitat of wetlands is due to agriculturally related sources. If Ontario's fisheries department spent $10 - $15 million to maintain fish habitats, then $6 - $9 million can be attributed to problems stemming from agricultural run-off.

These figures clearly indicate the important role that wildlife plays in society. However, it is very difficult to determine the value of something that affects society in such an indirect manner. It is also very difficult to quantify damages placed on the environment, since a large number of both water dwelling species (fish, plankton etc.) and non-water dwelling species (birds) are affected by excessive soil erosion and the pollutants found in sediment. Large amounts of soil erosion can upset the balance of the water and land ecosystems by significantly altering habitats or killing specific species vulnerable to sediment

or phosphorus. However, to be able to quantify changes in activities due to changes in the aquatic environment is beyond this analysis.

9.0 NATURAL PROCESSES

9.1 HABITAT REGENERATION

Successional change, including the eutrophication (result of nutrient enrichment from phosphorus) of lakes is a natural process. Excessive use of phosphorus for crop production often results in excessive phosphorus loading in waterways. This enhances the eutrophication process and thus successional changes in the structure and function of affected aquatic life. Two major changes in the biota involve plankton and fish.

Plankton, microscopic plants and animals found in open water are somewhat sparse in nutrient-poor (oligotrophic) lakes. Their absence is responsible for the characteristic deep blue appearance (in the absence of suspended sediment) of water bodies. As enrichment proceeds through the import of nutrients from surrounding watersheds, dominant phytoplankton are replaced by algae (which clogs filters, releases obnoxious and objectionable aromas and flavours). As nutrient enrichment proceeds, favoured fish (e.g. trout, char, chub or lake herring) are replaced by progressively less relished forms of fish such as bass, perch, pike and, later on, carp and sunfish.

The amount of natural eutrophication in a moderately sized lake during a human lifetime is virtually imperceptible. However, this natural process is escalated to a considerable degree by pollution. "A threefold increase in phosphates from the 1930's to the 1970's is attributable to two major sources; some 60 - 80% from household sewage - largely from laundry detergents; and some 20 - 40% from fertilizers washed off the agricultural land of the region."

Despite what we know about the harmful effects of excessive sediment and phosphorus loadings in water systems, it is very difficult to quantify the consequences to the natural environment - more specifically to habitat regeneration. We do know that there can be dramatic affects but unfortunately, to what extent is unknown. A rational quantitative analysis is

beyond the scope of this study and therefore habitat regeneration as a measurable benefit of reductions in agricultural soil erosion will not be included.

10.0 CALCULATION OF THE TOTAL BENEFITS OF SOIL CONSERVATION PRACTICES

Figure 10.1 illustrates the total cost reductions (benefits) in downstream activity on a per hectare basis due to reductions in agricultural soil erosion. The results indicate that the economic benefits obtained from a 10 percent overall reduction in soil erosion range around $2.89 per hectare. A 40 percent reduction should result in downstream benefits of $11.84 per hectare.

The reported benefits do not vary between scenarios A and B since different sediment delivery rates do not affect percentage changes in downstream sediment from the assumed baseline values.

The downstream impact is attributed mostly to sedimentation reduction versus phosphorus reduction. This occurs for two reasons. First, as noted in Figure 5.4, a 10 percent reduction in soil erosion amounts to only a 6 percent reduction in phosphorus loading because 40 percent of phosphorus is in a water soluble form. In contrast, sedimentation reduces by the degree of erosion control. Second, the larger downstream impact areas occur in sediment related areas, e.g., fishing and water treatment.

If there were appropriate means for economically evaluating the effect of damages on wildlife and natural aesthetics, this category might well outweigh any of the other reported impacts since the benefits on wildlife and natural aesthetics may be one of if not the most important in the analysis. We can, therefore, expect downstream impacts to be somewhat higher than they appear. Calculated impacts must be recognized as possibly just a starting guideline outlining the effects of reductions in soil erosion.

Figure 10.1 Dollar Savings Created by Reductions in Farm Soil Erosion

Activity	Scenario A				Scenario B			
	10%		40%		10%		40%	
	Sediment	Phosphorus	Sediment	Phosphorus	Sediment	Phosphorus	Sediment	Phosphorus
Water Transport	$0.15/ha	$0/ha	$0.59/ha	$0/ha	$0.15/ha	$0/ha	$0.59/ha	$0/ha
Commercial Fishing	$.59/ha	$.031/ha	$2.38/ha	$.13/ha	$.59/ha	$.031/ha	$2.38/ha	$.13/ha
Water Conveyance	$.10/ha	$0/ha	$.40/ha	$0/ha	$.10/ha	$0/ha	$.40/ha	$0/ha
Water Flow Control	$.273/ha	$0/ha	$1.09/ha	$0/ha	$.273/ha	$0/ha	$1.09/ha	$0/ha
Water Treatment	$.53/ha	$.21/ha	$2.12/ha	$.85/ha	$.53/ha	$.21/ha	$2.12/ha	$.85/ha
Swimming	$0/ha	$.03/ha	$0/ha	$.11/ha	$0/ha	$.03/ha	$0/ha	$.11/ha
Boating	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown
Sport Fishing	$.95/ha	$.025/ha	$3.79/ha	$.40/ha	$.95/ha	$.025/ha	$3.79/ha	$.40/ha
Wildlife	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown
TOTALS	$2.59/ha	$.30/ha	$10.35/ha	$1.49/ha	$2.59/ha	$.30/ha	$10.35/ha	$1.49/ha
TOTAL A & B	$2.88/ha		$11.84/ha		$2.88/ha		$11.84/ha	

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